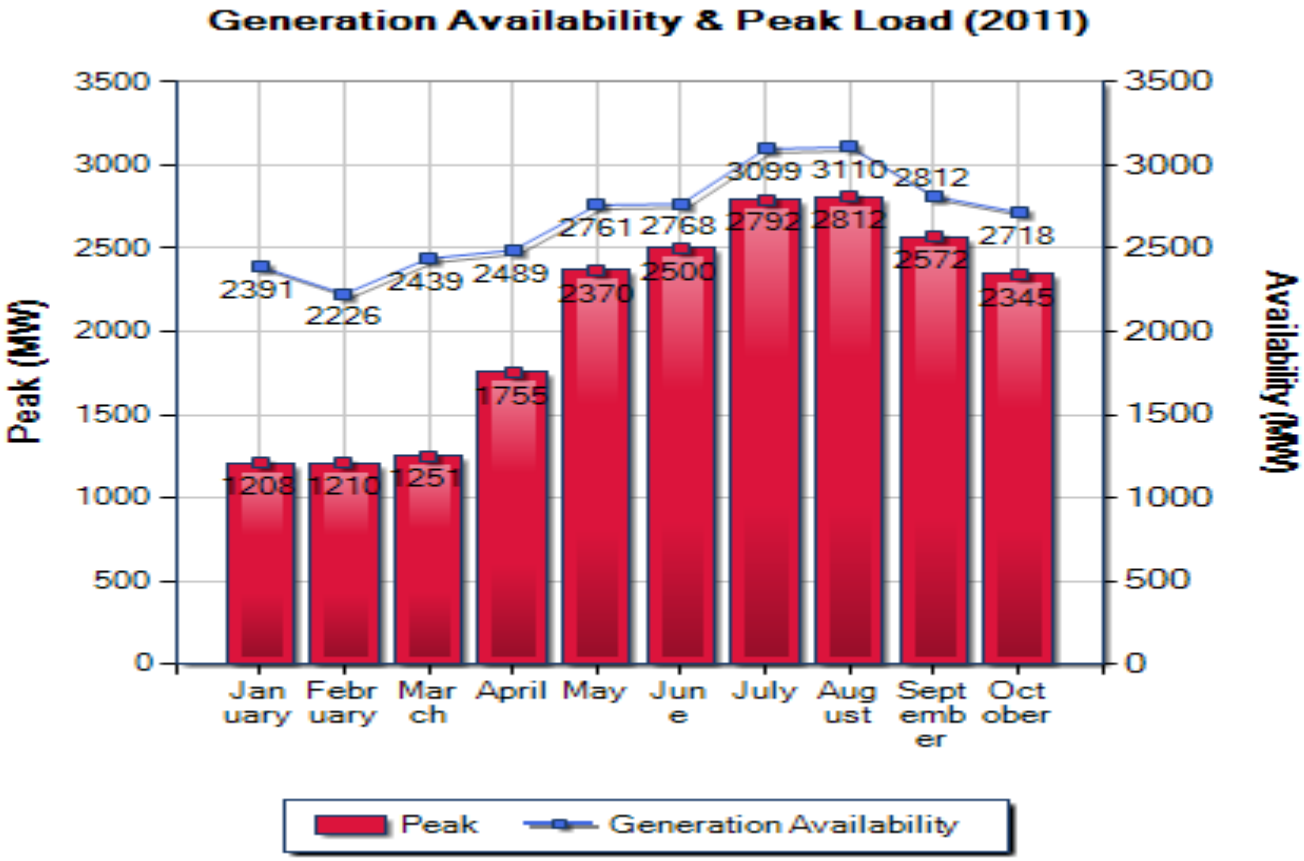
THERMAL INSULATION IN BUILDINGS-GUIDANCE TO ENGINEERING OFFICES
(Issued by Thermal Insulation Unit, Electricity & Water Conservation directorate)

A. INTRODUCTION

Why Thermal Insulation is required for Buildings in Bahrain?

The weather in Bahrain is very hot & humid during summer from May to October & cold during winter. Therefore air-conditioning of buildings is essential for human comfort. 47 to 57% of electricity demand in Bahrain during summer is for air-conditioning load as could be seen from chart given below which shows the month wise electricity demand during 2011:



Month	Peak Demand (MW)	Peak Demand for A/C (Increase over winter months) (MW)	A/C Demand (%)
January	1208	-	
February	1210	-	
March	1251	-	
April	1755	545	**31**
May	2370	1160	**47**
June	2500	1290	**52**
July	2792	1582	**57**
August	2812	1602	**57**
September	2572	1362	**53**
October	2345	1135	**48**

Using thermal insulation materials, in walls, roof & insulated glass for external doors/windows/curtain walls/sky lights, reduces rate of heat flow through building envelope from outside to inside during summer and from inside to outside during winter. Thermal insulation will thus reduce the air-conditioning (A/C) load during summer & heating load during winter, which in turn reduces the electricity demand for the building & electricity consumption..

Benefits to the building Client/owner:

- Reduction of capital cost for A/C equipment due to reduction of A/C load.
- Space requirements for A/C equipment and cost of plant room construction may be reduced.
- For H.V. consumers, saving on capital cost of Transformer(s), switchgear, cables required due to reduced electricity demand.
- Space requirement & cost of sub-station construction may be reduced.
- Less electricity demand means less capital contribution for electricity supply.
- Savings in electricity consumption charges (Lower monthly electricity bills).

Benefit for EWA:

- Electricity demand on the grid will be reduced.
- Transmission & Distribution losses will be reduced.
- Electricity generation requirement will be reduced.
- Demand for construction of new sub-stations will be reduced.
- Subsidy being provided by Government for domestic consumers will be reduced

Other Benefits:

- Due to reduction of power generation required, environmental pollution due to emission of flue gases from generating stations will be reduced.
- Better health for residents of Bahrain due to less pollution.
- Green house gas reduction will reduce rise in temperature levels & consequent rise in sea levels.

B. Thermal Insulation Regulations in Bahrain

A Ministerial Order (Order No. 8/1999) was issued in 1999 by H.E. The Minister of Housing & Municipality making it compulsory to provide thermal insulation in all buildings, which require air-conditioning, in Bahrain. The Order stipulates the following requirements:

1. Thermal insulation materials should be used for roofs and walls of all buildings which require air-conditioning according to the following:-

   a. The overall thermal transmittance value (U-value) for the roof should not be more than 0.6 $W/m^2\text{-}^oC$
   b. The overall thermal transmittance value (U-value) for external walls should not be more than 0.75 $W/m^2\text{-}^oC$.
   c. Insulated glass should be used for all buildings with more than three floors or if the area of the glazed surfaces ranges between 10-20% of the total external surface area of the building envelope. On the other hand, if the glazed area is more than 20%, double insulated glass should be used.

2. This rule shall be implemented for all new buildings, which need air-conditioning, and for the reconstruction of old buildings which require demolition of walls and/or roofs and for the extension of existing air-conditioned buildings.

3. To provide guidance to those responsible for the design, installation of thermal insulation in buildings in Bahrain, Ministry of Electricity & Water had issued in 2002 a code of practice for thermal insulation in buildings in Arabic and its English version was issued in 2006. The thermal insulation requirements implementation procedures are summarized below;

C. THERMAL INSULATION REQUIREMENTS

1. Thermal insulation shall be provided for all external walls including exposed columns, beams, stair cases and light wells/shafts. External walls of the building abutting adjoining building(s) if any shall also be insulated.
2. Thermal insulation shall be provided for the roof including swimming pool decks and stair cases/lift machine rooms.
3. Floors & walls of A.C. spaces exposed to non-air-conditioned spaces like car park/service areas in the building should be insulated.
4. Spandrel areas of curtain walls should be insulated.

D. IMPLEMENTATION PROCDURE:

The procedure for Thermal Insulation Implementation is given below:

Electricity & Water Authority | Electricity & Water Conservation Directorate

THERMAL INSULATION PROCEDURE IN BAHRAIN

PLANNING STAGE

Fill Thermal Insulation Implementation Form ⇒ Submit on-line to Municipality OSS and get Approval of EWCD ⇒ Obtain Building Permit from Municipality

Attach drawings and required supporting documents.

- Once approved, an application no. will be assigned for the building. If, during any stage, changes need to be done in insulation, owner name, engineering office etc., a *Modification Form* should be filled and approved by EWA.
- An application will be identified by its application no. (given in previous step) and the building permit no.

CONSTRUCTION STAGE

Send by Fax (No. 17006349) Follow Up Notice to EWCD ⇒ EWCD will contact you and set a date for inspection ⇒ EWCD will approve the implementation of Insulation

- Should be sent for each level, for the roof and glass at least 2 weeks before completion of insulation to allow for inspection
- In-charge engineer from the Engineering Office should be present during inspection.
- Once approved, EWCD may stamp the Follow Up Construction Form (Municipality Form). If not, insulation shold be modified in order to proceed to next level of construction.

It is the responsibility of all Engineering offices to adhere to and implement this procedure in its planning and construction stages

SUBMISSIONS BY ENGINEERING OFFICE

1. Planning Stage:

Required Enclosures for Enquiry Information Certificate:

Required Enclosures	Other conditions
a. Architectural plans for all floors highlighting the walls to be insulated.	Thermal insulation shall be provided for all external walls including exposed columns, beams, stair cases and light wells/shafts. External walls of the building abutting adjoining building(s) if any shall also be insulated.
	Walls of A.C. spaces exposed to non-air-conditioned spaces like service areas in the building should be insulated
b. Elevation drawings highlighting the floor slabs & roofs to be insulated.	All roofs & floors slabs of A.C. spaces exposed to non-air-conditioned spaces like car park areas in the building should be insulated

Required Submissions for Final Building Permit:

Required submissions	Other conditions
a. Thermal Insulation Implementation Form (Appendix-A)	All the fields should be filled, signed by client & in-charge engineer, stamped and all pages should be numbered..
	If wall/roof construction is different at different locations (such as shear walls, beams, columns, spandrel areas, swimming pool decks etc.) then separate U-Value calculation sheet with relevant data for each such location should be included
b. Supporting documents for thermal resistivity/thermal resistance values of materials used in U-Value calculations	Documents from manufacturer & test certificate from Testing Laboratories.
c. Calculation sheet for glass area as per prescribed format (Appendix-B).	
d. Calculation sheet for external surface area as per prescribed format (Appendix-C).	
e. Performance data sheets from glass manufacturer for each type of glass	
f. Architectural plans for all floors	In the Architectural drawings dwf file, show types of doors, windows, curtain walls as per the schedule of doors/windows/curtain walls in all floor plans.. Highlight the walls to be insulated.
g. Elevation drawings	In the Architectural drawings dwf file, show horizontal & vertical dimensions, types of doors, windows, curtain walls in all elevations. Highlight the floor slabs & roofs to be insulated.
h. Schedule of doors/windows/curtain walls/sky lights.	Include the schedule in the Architectural drawings dwf file,
i. Cross section drawings for each type of roof & wall with thermal insulation details.	One cross section drawing corresponding to each U-value calculation sheet in the TII Form should be submitted. Include these cross section drawings in the Architectural drawings dwf file or pdf file.
j. Layout of columns & Schedule of columns	Include in structural drawings dwf file
k. Layout of beams & Schedule of beams	Include in structural drawings dwf file

2. Construction Stage:

a. Follow Up Notices: (Appendix-D)	b. Follow UP Notice in the prescribed form (Appendix-D) should be sent to Electricity & Water Conservation Directorate (EWCD) of Electricity & Water Authority (EWA) during progress of construction for each floor, roof and glass, when intending to start installation of thermal insulation and at least two weeks before its completion.
	c. Copies of Building Permit and address card for **the entrance** of the building should be sent with **the first follow up notice**.
	d. If any violations in the implementation of thermal insulation were notified by EWCD, follow up notice is advisable to be sent when the rectification of such violation is being carried out.
b. Material Approval Form for Glass: (Appendix-E)	Approval of EWA should be obtained for the glazing by submitting material approval form for glass (Appendix-E) with performance data for the glass from the manufacturer, certificates from glass supplier & Aluminum fabricator (as per prescribed format-Appendix F) and one sample for each type of glass before execution.
	▪ Glass selection should be in accordance with Table (5.2) in the Code of Practice for thermal insulation in buildings.
c. Thermal Insulation Implementation Modification Form: (Appendix-G)	If the Engineering Office wants to make any changes in the Approved TII Form such as change of insulation materials in walls/roof, glass type, glass area etc., TII Modification Form (Appendix-G) should be submitted and approval obtained before incorporating any such changes in the building.
	Modification form should also be submitted for change of owner(s) & or Engineering office.
	Supporting documents required to be submitted, for each type of change proposed, are listed in the check list for TII Modification Form (Appendix-H).
d. Copies of delivery Notes for glass	Copies of Delivery Notes for glass from Manufacturer to local supplier & from local supplier to Aluminum Fabricator should be submitted at the time of glass inspection.
e. Copy of approved electrical load	Copy of approved electrical load from Electricity Distribution Directorate at the time of final stamping of Municipality construction follow up forms.

E. Thermal Insulation Design:

1. Definitions

- **Overall Thermal Transmittance (U-value) or Overall coefficient of heat transfer (U-factor):** This is the overall rate of heat transfer through a section per unit area and per unit temperature difference, expressed as $W/(m^2.°K)$
- U-value is the reciprocal of the overall thermal resistance ($1/R_T$)
- **Overall thermal resistance (R_T):** This is the sum of the thermal resistance of all material layers constituting the wall or roof section, and includes the thermal resistance of the outside and the inside air films in $(h.ft^2.{}^oF)/Btu$ or $(m^2.{}^oK)/W$. $R_T = (R_o+R_i+ R_1+R_2+---------+R_n)$
- R_o is the thermal resistance of the outside air film & R_i is the thermal resistance of the inside air film. These values are given in the Table below:

Section	Thermal resistance for adjacent air layer	
	Interior thermal resistance (R_i)	**Outside thermal resistance (R_o)**
Wall	**0.121**	**0.059**
Roof	**0.166**	**0.059**

- R_1, R_2, --------- R_n are thermal resistance of materials constituting the wall or roof section.
- **Thermal resistance (R) of a material** is the resistance to heat flow through a unit area of homogeneous material when there is a unit temperature difference between two surfaces and its unit of measurement is $(m^2-°C/W)$.
- Thermal resistance R of a material is calculated by dividing the thickness of the material by the thermal conductivity of the material (t/k) or by multiplying the thickness of the material by the thermal resistivity of the material.
- **Thermal conductivity (k)** is the property of the material, which determines the heat flow by conduction through unit thickness of unit area of the material across a unit temperature gradient. Thermal conductivity is influenced by the density, the porosity, water contents, and specific heat of the material. The unit of measurement is $(W/m-{}^oC)$.
- **Thermal Resistivity (r):** The reciprocal of the thermal conductivity (1/k) is the thermal resistivity of the material. It is the resistance to heat flow through unit thickness when there is a unit temperature difference between the two surfaces. In the metric system the unit of measurement is $m-{}^oC/W$.
- **Cavity Thermal Resistance (R_c):** It is the resistance of air in the cavity space to heat flow. It depends on the thickness of the cavity & the characteristics of the two surfaces enclosing the cavity. Following values could be used for thermal resistance of cavity (air space):

  - For a cavity which is more than 5 mm thick (up to 20 mm) (R_{air}) = 0.11 $m^2-°C/W$
  - For a cavity which is more than 20 mm thick (R_{air}) = 0.18 $m^2-°C/W$

2. Presentation of U-value Calculations:

- U-value calculation for walls & roof should be presented in the prescribed TII Form (Appendix-A) and signed by the client, In-charge Engineer with Engineering Office stamp & signature. **Include only the U-value calculation sheets applicable for the building.**
- The thermal resistivity or thermal conductivity values in the table "Summary of General Properties of Building Materials (Appendix-J)" may be used for calculating the thermal resistance.
- For materials not included in the above table, supporting documents for thermal resistivity or thermal conductivity values used in the calculations should be submitted.

F. Insulation Materials & Systems:

1. Wall Insulation:

Material/System	Merits	Demerits
a. Autoclaved Aerated Concrete (AAC) Blocks (Light weight white blocks; Thin-bed mortar (glue) as recommended by the manufacturer should only be used for the joints to minimize the thermal bridging effect of mortar joints. If ordinary sand cement mortar is used for joints, the U-value calculation for wall should take into account the thermal bridging effect of mortar joints.	Light weight: saves costs in foundation, building structure, labour etc. Easy to handle and time saving in construction. Easy to inspect. Higher price of blocks may be offset with above savings.	Price higher than insertion blocks. Separate insulation required for exposed external columns & beams.
b. Concrete Blocks with insulation insertions (Insertion Blocks): Blocks with insulation insertions to the full depth of slots, in 3 rows, at the manufacturer's factory should only be used. U-value calculation for wall should take into account the thermal bridging effect of mortar joints.	Cheaper compared to AAC blocks	Requires close and continuous supervision to ensure that insulation sheets are inserted properly in the slots and joints, which are to be done manually & improper insertions will result in thermal resistance value higher than the declared value. Not recommended as most of the violations noticed are due to improper insertions. Separate insulation required for exposed external columns & beams.
c. Cavity wall (double wall) filled with insulation: If the external wall is of double wall construction, thermal insulation can be provided in the cavity with insulating material such as rock wool, polystyrene etc. of appropriate thickness. The cavity should be water proof.	Provides much better insulation property. About 28% less Thermal Transmittance value could be achieved.	Though it may cost more, but on a life cycle cost would be comparable.

d. External Thermal Insulation Composite System: This system consists in fixing light thermal insulation boards, (usually expanded polystyrene boards using a special mortar on the external surface of walls), covering their surfaces with a mortar reinforced glass fiber mesh and then entire surface with a thin layer weather resistant plaster.	Provides joint less thermal protection for the entire external wall including external columns/beams resulting in no thermal-bridges.	
e. **Walls with internal insulation**: This system consists in fixing light thermal insulation boards (usually expanded or extruded polystyrene boards) on the internal surface of the wall and covering with plaster board.	Provides joint less thermal protection for the entire external wall including external columns/beams resulting in no thermal-bridges.	Size of the rooms on the periphery of the building will be reduced to the extent of thickness of insulation board & plaster board.

2. Roof Insulation:

Material/System	Merits	Demerits
a. Polyurethane Foam	Sprayed or foamed-in-place applications of polyurethane insulation are usually cheaper than installing foam boards. These applications also usually perform better since the liquid foam molds itself to all of the surfaces.	Potential health effects that may result from exposures to the chemicals if proper precautions are not taken during the application.
b. **Extruded Polystyrene**- ▪ Inverted Roof System with gravel protection. ▪ Inverted Roof System with concrete pavers. ▪ Inverted Roof System with concrete screed top.	The Inverted Roof system protects the waterproofing membrane from extreme thermal stresses, high ultraviolet exposure & mechanical stresses	Inverted Roof System with concrete screed requires provision of vent pipes over the separation layer on insulation boards.

3. Floor Slabs over/below Non A/C areas:

Material/System	Merits	Demerits
a. Soffit insulation with Polystyrene (extruded or expanded) covered with gypsum board		Fire classification is B2 (difficult to ignite), but flame spreads & smoke develops.
b. Soffit insulation with Rock wool covered with gypsum board	Non-combustible & excellent fire proofing material.	

Typical wall & roof construction details (cross sections) for the above insulation systems are given in Appendix-J

G. Glazing:

1. Glass Selection:

Glass selection should be in accordance with Table (5.2) in the Code of Practice for thermal insulation in buildings:

Table (5.2) Thermal performance of Glass.

Glass type	Shading coefficient	Relative Heat Gain (RHG) W/m^2	Percentage of transmitted light	U-Value $W/m^2\,^oC$	Remarks
Single Insulated	< 0.5	< 350	> 25%	< 5.1	Reflective glass with same specifications may be used
Double Insulated	<0.44	< 220	> 27%	< 2.4	The induced color in outside pane can affect the properties.
Curtain Wall	<0.25	< 160	> 18%	< 2.1	The more the curtain wall area, the stricter the specifications required.
Skylights & Roof Openings	<0.25	< 185	> 15%	< 2	The tightening of the units is a crucial issue.

Single insulated glass may be used for **doors/windows** if the % of glass area with respect to the total surface area is less than 20%. If the % of glass area is more than 20% then double insulated glass has to be used for **all doors/windows**.

2. Need to Minimize Use of Glass:

Compared to most other building materials, glass has the least resistance to ambient heat transfer which takes place by means of absorption, conduction and re-radiation.. The following table shows the comparison of heat gains for a solid wall construction & different type glazing for an outdoor/indoor temperature difference of 15^o C and solar heat gain factor of 693 W/m^2 for a west facing wall for 24^o North Latitude at 4 pm in the month of August.

Type of wall/glazing	Stipulated Maximum U-value $(W/M^2\,^oC)$	Stipulated Maximum Shading Coefficient (SC)	Heat Gain due to Conduction (15*U) W/M^2	Solar Heat Gain (693*SC) W/M^2	Total Heat Gain W/M^2
Insulated solid wall	0.75	-	11.5		11.5
Insulated Single glass	5.1	0.5	76.5	346.5	423
Insulated Double glass	2.4	0.44	36	304.92	340.92
Insulated Curtain wall	2.1	0.25	31.5	173.25	204.75

The Heat Gain due to conduction alone in single glass is 6.6 times, for double insulated glass 3 times & in curtain wall glass is 2.7 times that for a solid insulated wall. Considering solar heat gain, the total heat gain would be very high compared to insulated wall. Therefore it is always advisable to limit the use of glazing and avoid large glass facades especially those exposed to direct solar radiation such as the west and southwest.

H. Common Violations/Omissions Noticed in Thermal Insulation Implementation:

1. Procedural violations

Type of violation	Action required from Engineering Office (E.O)
a. Non Submission of Follow up notices (FUN) for walls floor wise during progress of construction	Ensure that Follow up Notice is sent for each floor when intending to start thermal insulation and at least two week in advance before its completion.
b. Non submission of copies of Building Permit (BP) & Address Card with first Follow Up Notice	Submit copies of BP & address card for **entrance of the building once only with first FUN**. No need for address card of flats.
c. Non Submission of TII Modification Form for changes in approved TII Form	E.O. should send a copy of the approved TII form to the client & contractor and advise them not to change thermal insulation materials in walls, roof or glass without obtaining prior approval from EWA. E.O. should submit TII Modification Form & obtain approval before incorporating any changes. Keep a copy of the approved TII Form/TII Modification Form at the site.
d. Completing the building without submission of follow up notices & thermal insulation inspections.	This is a serious violation of the Code of Practice. E.O. should be vigilant and ensure the procedures for FUN are followed strictly.

2. Violations in the Conduct of Thermal Insulation

Type of Violations	Action required from Engineering Office (E.O)
Violations in Walls Insulation:	
Violations related to use of insertion blocks:	
a. Insulation sheets not inserted to the full depth of the slots in the block.	Ensure that the insertion blocks are received with insulation sheets inserted to the full depth of all the slots at the factory and checked at site before their use. Blocks received without insertion sheets from the factory should not be accepted.
b. Insulation sheets not provided in the joints between blocks.	Instruct the Masons to insert the insulation sheets in the joints to the full depth while laying the blocks and site Foreman//Engineer should ensure that the Masons carry out the instructions without fail by proper supervision.
Violations related to use of Light Weight Blocks (Siporex/Alabyad/ACICO etc.)	
a. Use of ordinary mortar instead of glue or thin bed mortar for joints.	Ensure that only glue or thin bed mortar supplied by the Manufacturer is used.
b. Use of ordinary (uninsulated) blocks adjacent to window/door openings & columns instead of light weight blocks.	Manufacturer's should be consulted on how to fix the window/door frames to the walls with light weight blocks and follow their instructions instead of using ordinary blocks.
c. Use of Ordinary (uninsulated) blocks for walls of light wells/shafts, external walls in G.F., balconies, walls behind louvers etc. .	Walls of light wells/shafts open to sky and all external walls (even if they are in shaded areas like car parks, balconies, behind louvers) should be insulated. E.O. should instruct the contractor accordingly & use of ordinary blocks for the same should not be allowed.
Violations in Roof Insulation:	

Violations related to roof insulation with P.U. Foam	
a. Thickness of P.U. Foam less than the thickness given in the approved Thermal Insulation Implementation (TII) Form	Minimum thickness should not be less than what has been approved in the TII Form. E.O. should check the same before sending FUN for inspection.
b. Density of P.U. Foam is less than what was approved in the TII Form.	Specify the density of P.U. Foam to be the same as in the approved TII Form in the contract for water proofing and ensure its compliance.
c. Covering the P.U. Foam insulation with concrete screed before inspection.	E.O. should send FUN at least two weeks in advance before the completion of roof insulation & ensure that P.U. Foam insulation is not covered with concrete screed before inspection.
Violations related to roof insulation with extruded polystyrene:	
d. Separation layer not provided	Geo-fabric separation layer is required to be provided between extruded polystyrene and stone ballast or concrete screed. E. O. should ensure the same before sending FUN for inspection.
e. Vent pipes not provided over separation layer	If concrete screed is to be provided over the extruded polystyrene, vent pipes @ one per 50 m^2 of roof area should be provided over the Geo-fabric separation layer. E.O. should ensure that vent pipes are in place at the time of inspection. No need for vent pipes if stone ballast or loosely laid paving tiles are used over separation layer.
f. Using expanded polystyrene instead of extruded polystyrene approved for roof insulation.	Expanded polystyrene is not accepted for roof insulation as its water absorption is more compared to extruded polystyrene.
Violations related to glazing:	
a. Glass installed is different from the approved glass (different air space, different type etc.)	Submit Material Approval Form for glass & obtain approval of EWA before change to avoid rejection.
b. Clear glass is used in G.F. instead of insulated glass approved.	Only insulated glass is to be used. Obtain prior approval of EWA for any deviation from the earlier approval.

LIST OF THERMAL INSULATION SYSTEMS APPROVED BY EWCD

Sl. No.	System Name	Applicants Name & address	System Details
1	Roof Insulation System with extruded Polystyrene	Bahrain Building Matrix, P.O. Box 930, Manama, Kingdom of Bahrain	Inverted roof insulation system with extruded polystyrene covered with screed
2	Nova Exterior Wall Insulation System with Expanded Polystyrene	Bahrain Building Matrix, P.O. Box 930, Manama, Kingdom of Bahrain	External thermal insulation composite system with Nova expanded polystyrene panels
3	9" Leca Light Weight Block	Al Manaratain, P.o. Box 926, Manama, Kingdom of Bahrain	The Blocks are made of Leca light aggregate and similar to insertion blocks with Air spce slots & closed at the top.
4	Economical Concrete Casted Wall Insulation Systam	Al Khaja Est, Bldg. 282, R. 105, North Industrial Area, Kingdom of Bahrain	Cast in Situ Concrte Wall with Polystyrene Insertions.
5	AKG Light Wieght Blocks-Turkey	M.T.M Trading Company P.O Box 38873, Riffa, Kingdom of Bahrain.	Autoclaved, aerated concrete blocks.
6	ACICO Light Weight Blocks-Saudi	Al Mahmood, P.O. Box 520, Kingdom of Bahrain	Autoclaved, aerated concrete blocks.
7	Emirates Thermostone Light Block- UAE	Emirates Thermostone Co., P.O. Box 114197, Dubai, UAE.	Autoclaved, aerated concrete blocks.
8	Spetrum Light Block	Spectrum Light Block L.L.C., P.O. Box 9115, Abu Dhabi, UAE.	Autoclaved, aerated concrete blocks.
9	JMS EPS Sandwich Panel	Al Khaja Est, Bldg. 282, R. 105, North Industrial Area, Kingdom of Bahrain	EPS Sandwich Panel are composed of ordinary portland cement, expanded polystyrene foam sand as core material sandwiched with Calcium Silica Boards.
10	Polystyrene Blocks (Solid)	Realty World, P.O. Box 11987, Kingdom of Bahrain	The Blocks are made of cement, Dun sand, water & polystyrene beads
11	PAROC Panel System	Cottage Crafts, P.O. Box 511, Kingdom of Bahrain.	PAROC Panel consists of PAROC structural stone wool sandwiched between two steel sheets.