A classroom in the Danfoss learning centre at Chennai

Air Conditioning of Classrooms in Schools & Training Centres

By M. H. Lulla
Airconditioning System Designers, Chennai

Introduction

While addressing a gathering of engineers at a convocation, an eminent economist had said, "It is your privilege as a profession to elevate the standard of living of the society in which you live". This seems to have been said with an HVAC engineer in mind, the more so when that engineer works on projects such as school and classroom air conditioning system design. Schools are moulding blocks where young minds imbibe knowledge, and are called the crucibles of life.

Three or four decades ago, most schools merely installed ceiling fans for comfort and at best only one ceiling fan per classroom. Today, split air conditioners in classrooms have become quite common and the school managements of private schools use this feature to justify the large fees they charge parents. The questions that arise are: Is this type of air conditioning desirable? Does this type of air conditioning meet the minimum health requirements?

Air conditioning of school classrooms is a fairly recent feature and many managements save on costs by installing low cost split ACs to cater to tens of students within the room, without any provision for introducing fresh air. Lack of fresh air induces drowsiness and a heavy head in the students, making the teacher's job more difficult and ineffective. In extreme cases, where the AC units are noisy or acoustics is poor, school dropouts become high. A teacher should not have to compete with such odds.

Unfortunately, the authorities who can exert some control on the type of AC system to be installed, such as city or state education authorities, have not yet realized the importance

About the Author

M. H. Lulla is an electrical engineer from Annamalai University. He worked with Blue Star Limited for seven years before starting practice in 1973 as an air conditioning consultant, and has been working on diverse projects ranging from 5 TR to over 8000 TR, in applications varying from comfort cooling to process cooling to clean rooms. He has engineered close to 200 clean rooms, 200 auditoriums and several other projects. He has air conditioned the Green Building for Turbo Engineering which received over 62 credits to become one of the three top rated buildings in the World.

of laying down some minimum standards for AC systems in classrooms. Unless the school management is an enlightened one that cares for its students and how much they learn, most owners employ the lowest cost contractors as there is no guidance on the ideal temperature, humidity, fresh air quantity required per student and sound levels to be maintained. In the meantime, HVAC consultants have no choice but to depend on ASHRAE, USA Standards for guidance, as long as the owner's budgets are met.

The design of the air conditioning system for school classrooms is characterized by the following features and requirements and each item is explained in some detail later in the article, except items 1 and 2 which are self explanatory:

1. Most classrooms work fixed hours and work or break simultaneously
2. Work hours per year are small, around 1800 compared to 3000 in a general office and 8000 for a 24x7 facility
3. Occupancy per unit area is high and this necessitates equally high fresh air intake
4. Cooling loads are high and are more 'latent' than in, say, offices, necessitating the use of deeper coils and speed control on evaporator fans
5. Low noise level is most important
6. Good IAQ is a must, implying adequate fresh air and efficient air filtration
7. Proper operation and good maintenance are essential to maintain the classroom AC system in top condition

Indoor Air Quality (IAQ)

Indoor Air Quality is the nature of air that affects the health and perception of the occupants. Good IAQ primarily ensures minimal absenteeism due to continued good health of the students. Proper IAQ implies knowledge of the source of the likely pollutants.

Children comprise the majority of the school population; their respiratory and immune systems are not fully developed. The amount of fresh air they breathe is small. These two factors put together make them susceptible to air pollution. High occupant density is another unique feature which tends to increase air pollution and the risk of air-borne contamination.

Special areas in schools like laboratories, art classes, craft classes, vocational training classes and gyms tend to add unique varieties of contaminants.

A typical class of students in a school is made up of students from various backgrounds:

- Some have walked to school.
- Some have been dropped by parents on two wheelers.
- Some have come by cars.
- Some have come by school buses.
- Yet others use public transport like trains and buses.

The transit time of the student to reach school could vary from a few minutes to over an hour. During this transit period, each individual is subject to picking up pollen, dust and other contact contaminants which can trigger infection and disease; while control of these may not be exactly an air conditioning system engineer's job, suggesting solutions like the use of head-dress and overcoats helps in reducing contamination risks. Properly ventilated locker rooms for keeping head gear, street shoes and coats would be necessary to make this work.

A lot of pre-school and kindergarten classes have adopted the practice of placing toilets which open out to the classrooms directly; these are convenient for the teacher and the child but are dangerous from a health stand-point.

Instead of just increasing the fresh air intake of the AC system to dilute the above pollution, the design engineer should work with the school team. His aim should be to manage pollutant sources and using ventilation to control air-borne contaminants.

Control of Pollution

The following methods can help to lower contaminants of indoor air pollution.

Source Collection

Catch all pollutants at source – the visible effect of any pollutant is dust, fibers, mould, gases, etc. and the sources could be internal or external. The best form of control on these would be to avoid getting them into the building – or in the case of internal contaminants – these must be collected at source. For example, keep drive ways and parking areas away from FA intakes.

It is a common perception that all school going children tend to catch a cold 12 times a year and parents of school going children catch it six times a year. This frequent occurrence can be traced to sneezes and the subsequent entrainment of aerosols into the air and deposition on other students. The best control one can exercise on such pollution is to train the children to catch the sneeze in a handkerchief (source collection).

Source Substitution

This would include selecting proper less toxic building materials and finishes, using phenol free boards, and low VOC paints.

Local Exhaust

This prevents cross proliferation of contaminants from defined areas like toilets, labs, craft classes, etc. to other areas. In addition to rest rooms and kitchen, a school would call for proper exhaust from labs, housekeeping store rooms, printing and Xerox rooms, workshop, etc. This exhaust should be funneled out at selected points.

Ventilation

ASHRAE standards set down the minimum rates of ventilation air. These must be implemented with a provision to provide for excess when desired for flushing etc. Fresh air intake of 30% more than ASHRAE requirement would be ideal for a school.

A lab may have a bottle of reagent broken or spilled. For handling such chance pollutants, a large wall-mounted fan (with gravity louvers) is a welcome equipment. Such 'scavenging' fans are run on bell switches, i.e. they run only when a person keeps the switch depressed. This ensures supervisory control of the fan on/off on a need based cycle.

Exposure Control

This is for covering time related pollution activities like painting, pesticide fumigation etc. There should be provision for flushing/ scavenging (may be even excess FA for the AHU to run) to dilute the pollution related to these time related activities – these may be scheduled for off peak load times, too.

Air Filtration

Control on dust means that items like bacteria and allergens are automatically restricted. For effective control of bacteria, at least 5 micron dust should be trapped. Filters capable of capturing 5 micron dust even with 95% efficiency – MERV 13 – and having large filter paper areas provide for effective contamination control, and do not increase the fan static much. Filter cleaning to suit the filter manufacturer's protocol is a must. Filters need to be freely accessible to personnel standing on the floor, not while working from ladders. Proper filter guides and good fixing attachments must avoid air bypassing the filters. Filter fixing by quarter turn devices is advisable as opposed to screws.

Proper Education

The most important aspect is that all occupants of the school – teachers and students – must be aware of the proper air-ways (passages for both SA & RA); and they must ensure that their role, if any, should be adhered to. For example: (1) Not running toilet exhaust fans, for any reason what so ever, increases the risk of contamination. (2) Not catching a sneeze in a handkerchief increases the chances of your neighbor catching a cold. (Research has documented that a sneeze could remain suspended in the air of a classroom for as much as two weeks if not captured in a handkerchief). (3) If locker rooms are provided, there should be a proper protocol for removing street shoes, overcoats, umbrella etc. Proper locker room ventilation goes a long way in ensuring good IAQ.

Noise in a Classroom

Noise emanates from two broad sources – external and internal. External noise control is an issue more to do with the architectural features, like site selection, building design, etc. Internal noise is largely attributable to the HVAC equipment. External noise is not discussed in this article, as it can be the subject of a whole text book.

In the more advanced schools – where electronic boards are in use extensively – one may find noise cancellation systems also. These cancellation systems counter and cancel unwanted noise. In such applications, mechanical equipment noise control can be put in the background. This kind of application apart, HVAC noise control is very important. One may even say that it is the single largest feature which sets school air conditioning apart from other applications.

Noise control in classrooms is more challenging due to factors like:

- Increased quantity of fresh air – means bigger equipment.
- The need for high energy efficiency and the consequent attempts to use energy recovery systems – meaning more fans and ducts.
- Difficulty in using soft, noise attenuation material to suit code and community needs from a stand point of health, hygiene and safety.

In a classroom, ideally the only noise one hears should be the speech of the teacher – but in practice what reaches the student's ears is not only the speech but also:

- Reflected noise (or reverberation), and
- Noise from HVAC equipment.

Reverberation is largely an architectural feature which is based on the dimensions of the classroom and its inside finish. A small amount of reverberation is acceptable and even desirable as it provides reinforcement to the speech – but too much is likely to affect the speech and the speaker. Here again, a good school architect takes proper care of this feature, and this point is not discussed further in this article.

Sources of Noise

HVAC noise in a classroom can be from fans, pumps, chillers, condensers, ducts and even grilles and diffusers. Such noise, reinforced by poor classroom acoustics (excessive reverberation) can make speech assimilation very poor. This has been known to lead to excessive class dropouts, particularly of students who have some hearing loss, even at levels as small as 25 db. The human ear and brain have the ability to automatically filter desired information from the extraneous noise, but the additional work load of this filtration reduces the attention span of the brain. Unfortunately, this drop in attention happens long before one recognizes a significant problem of noise or reverberation.

Most codes call for 30/35 dB for classrooms 750 sq ft and above, and permit a 5 dB relaxation i.e. 35/40 dB for smaller classrooms. In laboratories and art classes, where the speaking distance gets shorter, the ill effects of noise are known to be lesser. This is because non verbal forms of communication, like gestures, gain importance.

Noise Control

Noise control would need to be addressed as a system concept and to take into account:

- Type of equipment,
- Its location, and
- Sound travel paths.

The basic rules to remember in noise attenuation are:

- Noise travels in straight lines. This means what you do not see is heard less.
- Noise attenuation respects mass. This means if there is a 'barrier' between the source and the recipient, noise is reduced.
- Noise attenuation respects distance. This means if the source is remote from the ear, it is heard less.

Evaporator Fans

These are the mechanical equipment likely to be the closest to the human ear in a classroom. The noise travel from these

continued on page 56

continued from page 54

is generally through the air. Most commercially available fans are not likely to meet the acoustical code requirements if they are put in a classroom directly, hence attenuation would be desirable. This can be achieved by locating the fan at a distance or putting it one wall 'away' from the ear of the recipients, i.e. increase the distance or add mass in the line of noise travel. The wall should have a minimum density of 40 lbs/sq ft. Silencers cannot be considered on commercial unit type equipment like splits, as the fans would not be able to handle the extra static in the air path due to these.

A good 5 TR ductable split unit with a grille or fan discharge can have a dB reading as high as 70. If a GI duct 10' long is put on its discharge, and air discharge is effected through a grille on the side of the duct, the reading at the outlet goes down to 60 dB. The small length of duct and change in direction can achieve 10 dB attenuation.

Pump noise generally reaches a classroom through structural transmission. The pump vibration transforms to noise. For pump noise control it is very necessary to install these on proper vibration isolators. A floating concrete base for the pump is desirable; more importantly, the piping from these pumps must get the same care regarding anti-vibration supports as the pump itself. Pump bases must be at least as heavy as the whole pump set put together for proper dampening of the vibration without causing a strain on the pipes.

Chillers

Chiller noise may be treated on the same lines as pump noise. A chiller has a lot of static mass compared to the weight of the compressor; therefore one can dispense with a floating RCC base. The chiller can be floated directly on anti-vibration (AV) mounts (without any additional mass). Most chiller manufacturers give firm recommendations on AV mounts; these need to be followed faithfully.

Condensers

They are generally an integral part of the chiller. Air cooled condenser fan vibration is generally of no great consequence, but the fan noise (directly cutting air) has been known to be more predominant than compressor noise – particularly where rotary compressors are in use, housed inside casings. Air cooled condensers are best located on the highest point of the building. There should not be a straight line path from these to any classroom window/ door. In other words, such equipment is best located so that they cannot be seen from classroom windows/ doors. Noisy condenser fans have been known to influence subjects as much as 20m away from them.

Cooling Towers

They generally need the same care as air cooled condensers. The fan decks of cooling towers, or the whole tower itself, can be floated on springs. Critical use buildings like the Air India building in Mumbai used AV mounts for the towers when they were built.

Roof top equipment in general, such as chillers, must be kept on specially designed stiff heavy duty RCC roof slabs which are designed for a minimum loading of 1 ton per sq m (though in most cases the actual load does not exceed 500 to 600 kg/ sq m). These equipment slabs are best positioned over areas which are not critical to the teaching aspect of the school. Equipment running at speeds lower than 1500 rpm needs more care and is best mounted on sub-bases which float on springs having a minimum static deflection of 20 mm. If the roof slab is not 'stiff' as mentioned earlier, one may need larger static deflection in the AV mounts of the floating base. The larger deflection would call for similar increase in the pipe supports as well.

Grilles and Diffusers

Most manufacturers today give excellent data on their products. It is very necessary to use these for a proper selection. One should keep in mind that the manufacturer's data is generally based on 10 dB attenuation of the room. This attenuation is not likely to be available in an average classroom. This is because most classrooms still rely on wooden furniture. Upholstery, carpets and special false ceilings are rare in a classroom, though these are desirable for proper attenuation. These soft materials are not used due to considerations of hygiene, cost, housekeeping, etc. Corporate learning centers (training rooms) use these materials and have proper attenuation for internal noise; grille selection is easier here.

Grille and diffuser noise is due to air pushing past a multitude of small, closely spaced elements like equalizers, dampers, rear vanes, front vanes, etc. Quiet diffusers are characterized by lesser number of vanes, wider spacing and proper aerofoil extrusion shapes. Dampers that are 50% closed for air balancing can be 7 to 10 dB noisier than fully open dampers, hence the need for proper size selection. Ideally, side blowing grilles should not be used as they make it very difficult to make the room 'draft free'. Side blowing grilles, when located in walls, must have at least 300mm height of wall above them; otherwise the noise from these grilles tends to get amplified due to proximity to the ceiling.

Operation & Maintenance of Air Conditioning Equipment for a Classroom

The best words on O&M come from the air conditioning plant manufacturer's (or contractor's) manual. These manuals are comprehensive and very useful. Reference and faithful use of these manuals is a must.

The single largest routine maintenance item would be cleaning of the air filters. The air conditioning equipment must have freely accessible filters to make such cleaning simple. The next important item is to ensure that the drain pans are clear and do not hold any condensate. Generally, equipment concealed in a false ceiling void is not in the best position to provide for these needs.

O&M manuals are written for air conditioning systems in general. School air conditioning is a special case, since schools work for not more than 200 days in a year – they have long periods of shutdown like the summer vacation, winter vacation

continued on page 58

continued from page 56

etc. During the holidays, the staff rooms and administrative areas work. A school air conditioning system can be designed to have a separate plant for the administrative areas and staff rooms, and a separate plant for the classrooms. All the outdoor equipment of the classroom system can then be covered over with white plastic tarpaulin sheets when not in use. The white colour reflects the heat and the plastic sheet protects the equipment from dust and atmospheric corrosion. Atmospheric corrosion is a big factor in places like Chennai and Mumbai, which have oceanic coastal climate with high salinity. Such covers extend plant life substantially.

Plastic covers may be plain sheets spread over the equipment with liberal overlaps, or custom made covers like a car cover. They can be numbered and marked to suit the tag numbers of the equipment they cover. They can be cleaned and reused again and again, and barely cost two rupees a square foot. Plastic dust covers are best stored in metal boxes in proper store rooms. They should never be left in AHU rooms as they pose a high fire hazard.

A corollary to the long shutdowns is that insects and vermin tend to get into the RA voids and equipment during the shutdown periods. Some good steps to combat this problem are:

- Restrict eatables in classrooms.
- Adopt proper vermin control and pest control.
- Inspect and clean every RA void. (This pre-supposes that RA voids have been made accessible and cleanable).

The Dr. N. G. Palaniswamy School described in the case studies below addresses the need for a proper design to make O&M easy; all the mechanical equipment for the school is on the roof top, out of reach of students but easily accessible to maintenance.

Case Studies

Case Study – A: A State of the Art Classroom

Dr. N. G. Palaniswamy School at Coimbatore decided to go in for air conditioning even when the school building was being planned. In its first phase of construction, the school would have 40 classrooms, labs, library as also staff and administrative areas spread over 3 floors (ground + 2 upper floors). The rooms were built around two courtyards which would be covered on the roof to cut off rain water but still provide free space for movement – large corridors were proposed. The furniture would be wooden, and the school would give importance to health care and cater to the elite. The average classroom was 600 sq ft. The above gets translated to AC design parameters as below:

For the heat load design factors:

- Fresh air was pegged at least 30% over ASHRAE requirements
- Noise level was pegged at 40dB
- Good filtration (5 micron – 95%) was specified
- Outdoor units need to be remote – preferably on roof top

The above inputs led to the conclusion that:

- Commercial unit type factory made equipment cannot be used for placement in the classroom.
- Each classroom with a load of barely 5 tons is too small for independent AHUs (in separate AHU rooms).
- The administrative and staff areas have almost double the operating hours of a classroom and would need the flexibility of being able to run individually at any time.

System design – the above requirements were met by:

In general, a stack of 3 classrooms – one on each of 3 floors – would have a common 15 TR AHU placed on the roof top. A masonry shaft from this AHU room would drop down to the 3 classrooms below the AHU room. The masonry shaft would allow for placement of an SA duct within it, and

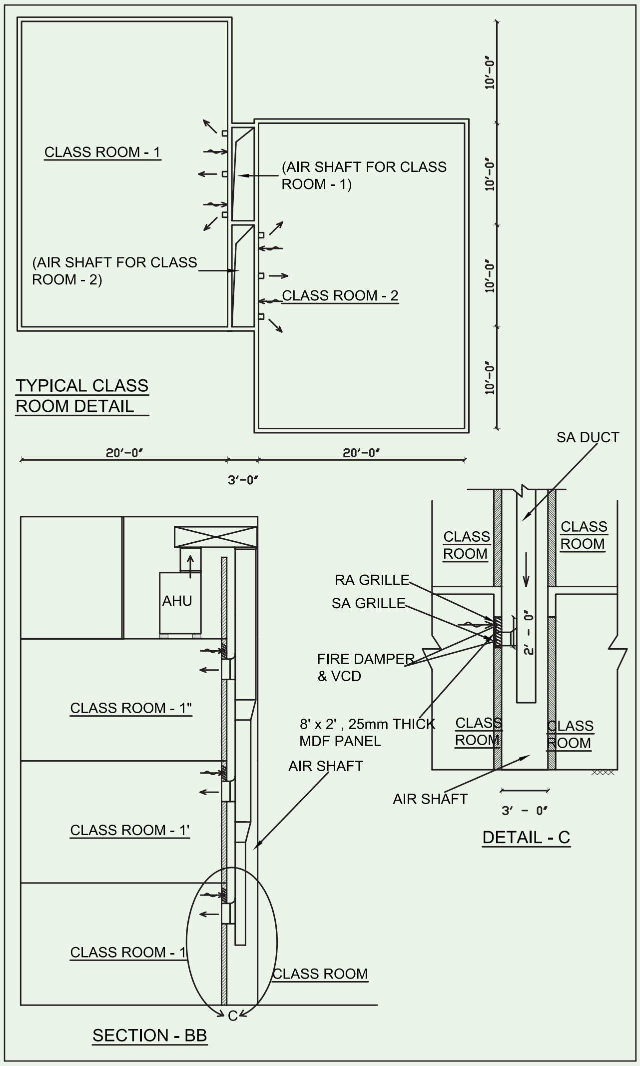

Figure 1: Typical classroom and section details

continued on page 60

continued from page 58

the masonry shaft would be used as an RA plenum. Each class would have a side wall grille for SA and RA; SA and RA openings in each classroom would have proper fire dampers. There would be no false ceiling or inaccessible RA voids to house vermin etc.

A chilled water system of 200 TR with 2 x 100 TR air-cooled screw chillers would meet the cooling needs of the 16 AHUs for the classrooms, and 5 x 10 TR VRF systems would provide the cooling for the administrative areas. Please see *Figure 1* that shows typical classroom and sectional details.

There would be 16 AHU rooms each with a masonry RA shaft 3000 mm x 900 mm dropping down to the ground level. SA GI ducts would be lowered into this shaft. Aluminium ladders would be screwed into the side walls of each shaft and there is lighting within each shaft.

Each shaft fronts out into the middle of a classroom and has openings at every floor level for the SA and RA grilles of each classroom.

5 x 10 TR VRF ODUs connect on to suitable indoor units on the lower floor to cool the administrative areas and staff rooms.

There are chilled water loops for supply and return chilled water on the roof top, which also houses the power panel rooms, BMS rooms, etc.

The key points desired in the design programme have been met, and the additional benefits of the system are:

- The entire AC system is virtually on the roof.
- The entire classroom AHUs can be serviced (including filter cleaning) from the roof.
- All the units are on a powerful BMS.
- No class has any mechanical equipment, meaning that you do not have any AC maintenance people on the academic floors.
- Remote located AHUs for each class mean improved acoustics.
- The RA void is 100% accessible and has lights for periodic inspection and housekeeping.

Case Study – B: Training Centre of an International Bank – Retrofit

An international bank's back office division sited in a multi storeyed building in Hyderabad had a total area close to 20,000 sq m spread over 7 floors – each floor having about 3000 sq m of air conditioned office space. Each floor was cooled by 2 AHUs of 95 TR each. The bank decided to convert a major portion of one floor to a training center. The

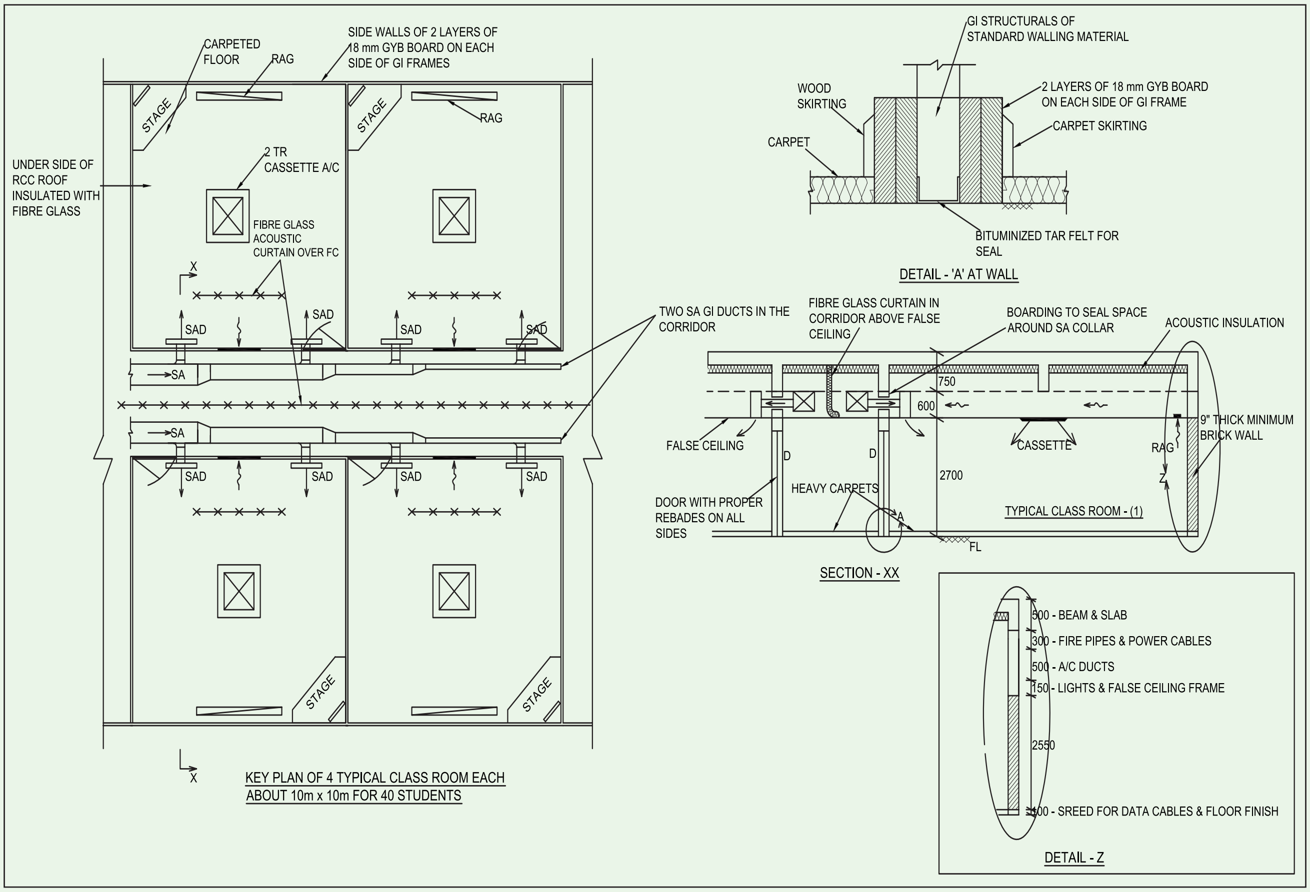

Figure 2: Typical classroom AC schematics

continued on page 62

continued from page 60

design programme for the training center called for about 40 classrooms of 60 sq m each and the ancillary administrative facilities. Acoustics was of paramount importance and cutting out cross talk was the biggest challenge.

The cooling load for the floor would increase due to increased FA and occupancy. Each classroom was equipped with a 2 TR cassette type VRF unit. This provides an element of 'TAC' air conditioning whereby each classroom can call for a temperature of its own choice. About 40% of the peak load is met by the cassette, and the balance 60% load is met from the central system – the 2 x 95 TR AHUs were slowed down to increase their latent heat handling capability; cfms were down from 400 per TR to 300 per TR, making duct sizing manageable and grille sizes small, reducing the risk of cross talk. No side wall grilles were used for SA; only slot linear diffusers were used, as the plenum used on them gives the desired change in air direction for noise attenuation.

Return air was collected at the remote end of a classroom false ceiling void. The RA path was acoustically insulated and the openings in the side wall of the classroom (over the false ceiling) were shielded from one another by simply hanging fiberglass mats (2" fiberglass wrapped in RP tissue and held in place by chicken wire mesh).

Figure 2 indicates the above as also other important factors taken care of in putting up the partitions.

Case Study – C: Classrooms of the Training Centre of an IT Major

Training has become a very powerful tool in ensuring proper cohesion in any organization. It goes a long way in ensuring quality of the product being produced and safety at the work place. Even mundane jobs like housekeeping now attract attention from trainers. Companies like Coco Cola have training classes for workmen who do the smallest work like bottle washing, housekeeping, fork lift operation, etc. IT companies, of course, need training on a larger scale.

Figure 3 shows the key plan of a typical floor of a four floor training center, which has close to a dozen classrooms per floor. It also shows a blown up detail of one of the typical classrooms.

The classroom has a cooling load of about 9TR; 4TR is met by 2 cassette type AC units and 5 tons by air from a central AHU. The central AHU sited on the ground floor blows air into a vertical shaft four floors tall. Branches from this stack cool one classroom each at each of the four levels above the AHU. The 5 tons of cooling air from the AHU for each classroom handles all the FA needs of the classroom and a part of the room heat also; the cooling from the AHU is adequate for off peak usage (i.e. with less occupancy or at nights and in the monsoon). Peak usage would call for the VRF cassettes to cut in automatically to meet the increased cooling needs. The cassettes are connected to a VRF system ODU, and are

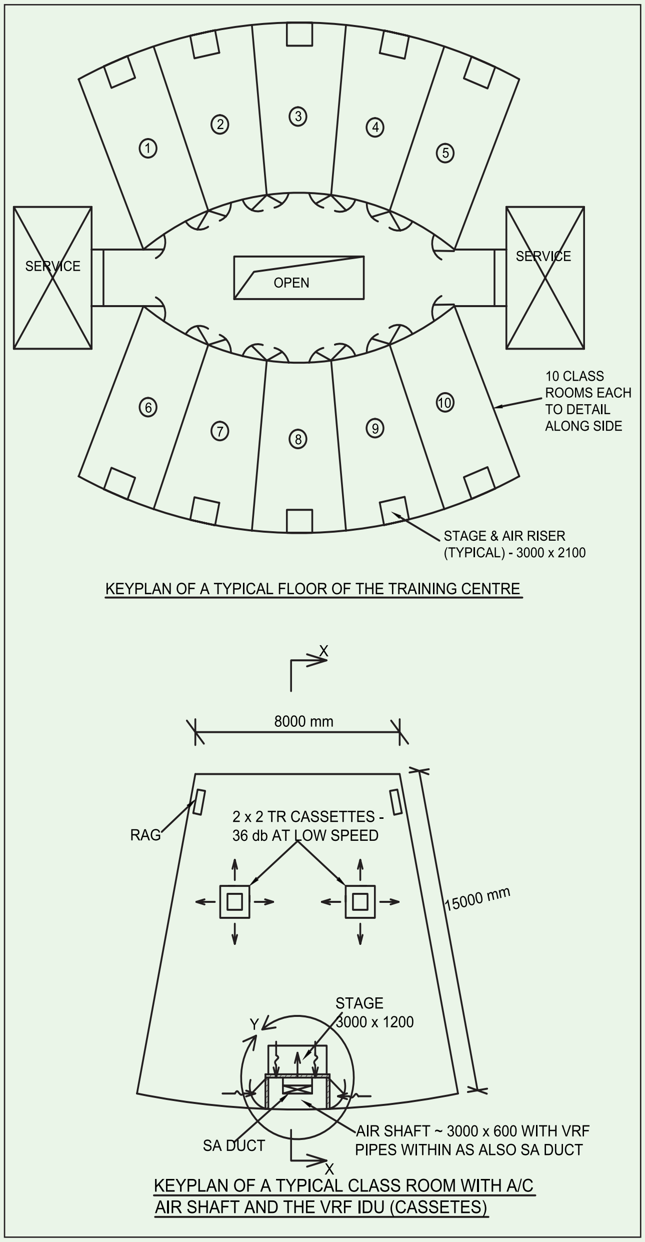

Figure 3: Key plan of a classroom floor

responsible for temperature maintenance. At low speeds the VRF cassettes, when selected properly, are capable of operating at 36/38 dB.

The AHU is generally always on and meets the base load of the classroom. When the temperature rises, the cassette cuts in. The VRF cassette is able to follow the temperature requirement with greater fidelity than any other system; hence temperature maintenance in the classroom is good and even. The ten AHUs of 20 TR each are connected to a 200 TR chiller system (2 x 100 TR screws), and the VRF cassettes 10 x 2 TR each in a vertical stack – one over the other – connect to a 15 TR VRF - ODU kept on the roof top. ❖