Paper No: 746 Generic Repeat Design Schools Ireland

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Abstract

The Generic Repeat Design (GRD) Schools programme is not just a once-off demonstration building. The design utilises the best of currently available design techniques and proven technologies in the building. The GRD school project consists of a design for a standard 8, 12, and 16 classroom school. The overall energy impact of the design is considerable as 50 plus schools will be constructed to this proven and optimised, low energy design. In addition to producing a building design that uses less than 50% of the energy used by a school built to CIBSE good practice standards without significant additional cost, the GRD schools program allows school projects to be fast tracked, and has a huge potential to reduce the environmental impact of Irish schools within a short time period.

Keywords: low-energy school, standard template school, passive solar design, natural daylight.

1. Introduction

1.1 Practical Simplicity

The Generic Repeat Design (GRD) is a programme delivering many schools, not just a single demonstration prototype building. To minimise risk on so many projects, it brings together proven-in-use technologies. It is significant because of the practical simplicity of its low energy design and repeatability on sites with varied orientations.

Fig. 1 South facing 2-storey classroom block & entrance of first completed GRD School.

1.2 Precedent

There are clear precedents in Ireland for the use of highly refined standard school plans as part of government response to the demands of providing accommodation for large numbers of pupils. Many of these schools from earlier decades have stood the test of time and reinforce the school as significant building type in the Irish rural and urban landscape. The GRD has evolved this procurement method with complete superstructure tender packages available, copyright of these designs is owned by the Department of Education and Science. As a result a limited service is required of site-specific consultants to deliver GRD's on individual sites. The resultant fee savings have more than offset the enhanced small additional premium for future-proof elements in the design.

1.3 Previous Research

A review of international leading edge research in school design was undertaken. The experience and feedback from the design and performance monitoring of the CIBSE award winning school project, Gaelscoil an Eiscir Riada, Tullamore, Co. Offaly, were fully considered. While this pilot or once-off building was a test-bed for a number of technologies, given the requirement to minimise risk on multiple projects, the GRD brings together all currently available proven and tested-in-use technologies.

1.4 Scope and Intent

The scope of this project is to develop a two-storey primary school core of 8 classroom extending to 12 and 16 classrooms, which can be repeated in a range of locations.

They have been designed to comply with the Irish Department of Education and Science's accommodation brief, area limits, and new technical guidance documents.

This was achieved keeping within the Department of Education and Science strict cost limits, with a small additional premium to cover the additional costs to comply with pending insulation standard regulatory improvements. The overall design is thus future proofed. The GRD schools program allows school projects to be fast tracked utilising type plans, and has a huge potential to reduce the environmental impact of Irish schools within a short time period.

2. Architectural Response

2.1 Compactness

The footprint of the two-storey solution offers increased benefits in its compactness, better land-use, reduced building envelope, and compactness for extending. It contributes to ease of management, better supervision, security and sense of connection between spaces.

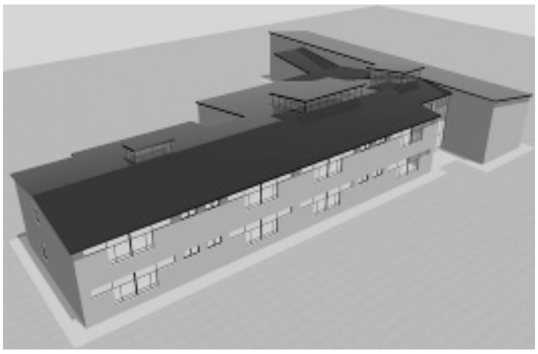

Fig 2. 3D Model of compact form & simple roofs

2.2 Double-height entrance space

This is the single most effective organizing element in the building, facilitating the generic entrances at either end, contributing to internal orientation, clear way-finding - a critical need with the integration of special needs pupils. Views to and from upper level balcony corridor into Hall give a sense of transparency, visual connection, and passive supervision. The roof lanterns with atrium below enables daylight penetration into the depth of the block in the circulation spine, reinforcing it as the heart of the school. Void with stairs rising to upper level emphasises unity of entire school as "children's' house", and reflects the progression of children through school age years. It is protected at the at first floor corridor level by a translucent guardrail 1400mm high.

Fig 3. Double-height entrance atrium with stairs to First Floor & glazed screen to school Hall.

2.3 Materials

All building materials and forms of construction were selected on basis of whole life-cycle analysis, optimising ease of build, sustainable products, durability and low-maintenance.

2.4 Extendibility

The 8-classroom school acts as core containing all ancillary spaces, including school hall, and allows for extending to 12 and up to 16 classrooms. By locating fire stairs at corridor ends, it is possible to add further extensions in two directions, for example a special unit, extra resource teaching rooms, or classrooms, with minimum disruption to the school in operation.

2.5 Security

With child safety as key criteria, the school embodies passive security strategies in the building as well as active elements. Passive elements include a strong entrance to give clear direction, a secure vetting of visitors lobby. Within the school passive supervision is enhanced by the central atrium and glazed screens. The two-story approach also reduces ground accessible perimeter.

2.6 Acoustic Environment

Aware of acoustic problems in some recently completed schools, mainly arising from the use of new materials and construction methods, an appraisal of school acoustics was required and an acoustic specialist was appointed. In the absence of an equivalent Irish Standard, the UK Building Bulletin 93 *'Acoustic Design of Schools'* was adopted as a benchmark of international best practise. A good acoustic environment is provided in all spaces, essential for the integration of Special Educational Needs (SEN) pupils, particularly hearing and visually impaired, autistic and dyslexia.

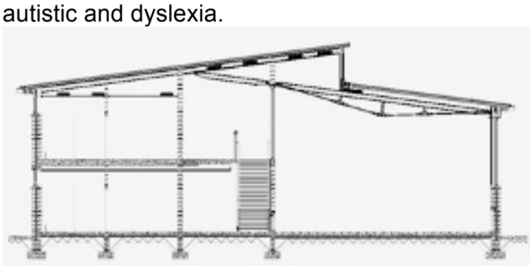

Fig 4. Cross Section thru' Classrooms, Double height Atrium Stairs & School Hall

3. Application of GRD models

- in areas of changing demographic patterns where expansion is foreseen.
- in areas where both mainstream and special needs provision are required.
- where swift provision of primary accommodation is essential.
- in areas where land is expensive and where sites are limited or restricted in area.

4. Benefits of a GRD

- a fully considered educational model.
- extendibility and future-proofing potential of the initial core school.
- timeline savings through the application of an off-the-shelf solution.
- reduced Professional Fees.
- more sustainable land utilisation consistent with higher densities residential development guidelines, thus improving the yields on serviced lands.
- improved internal environments.
- reduced cost-in-use, whole life-cycle and maintenance costs.
- model allows for the substitution of materials for site specific reasons
- greater cost certainty in budget projection and planning of schools' capital programme.
- elimination of the compromises in specification that are often made in order to stay within tight cost limits.

- R+D has contributed to a rationalisation of space norms and improved output performance for all primary schools.
- R+D has contributed to other initiatives, e.g., Design and Build, PPP, through the preparation of the output specifications, and template or benchmark designs.

5. Passive Solar Design

5.1 Key Principals

The following are the key principals in passive solar design for a primary school in the Irish climate:

- A larger area of glazing should face towards the sun than away from it.
- Deeper rooms should be provided with glazing that faces the sun. (The total floor area of rooms with windows facing the sun should be larger than the total floor area of rooms that do not face the sun).
- The orientation of the sun facing windows should take into account the short operating day of a primary school 9.00am to 3.00pm, and that most heating energy is needed during the early stages of the day. (Solar gain admitted late in the day, after the building is heated up and the building heating system is turned off is of limited use).
- Rooms that are operated at a cooler temperature should face away from the sun as they do not require as much heating.

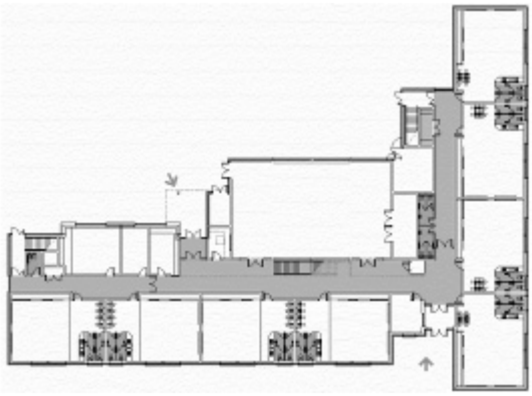

Fig 5. Ground Floor Plan – South & East facing classrooms. Alternative South & North Entrances.

5.2 Orientation

The orientation of a school building has a significant effect on its heating energy use and also has an effect on the usefulness of daylight provided. Simulations were carried out for two school buildings that were identical in their accommodation provision but with alternative orientation arrangements. The school that was oriented to take advantage of passive solar gain was shown to require up to 25% less heating energy.

If classrooms are oriented to achieve good natural daylight levels early in the morning, then the lights will not be turned on when the occupants arrive in the building. This tends to set the scene for the day and makes the occupants more willing to accept varying natural daylight levels, without over dependence on often unnecessary artificial lights. Lighting levels are also higher from south facing sunlight even in overcast conditions. Sunlight enlivens and adds sparkle to these most important classroom spaces - the day-long base for primary school pupils aiding a sense of well-being.

The generic school design has been arranged with its classrooms facing both east and south to take advantage of early morning sun. The school Hall, plant room, switch room, stores, and stairwells have been placed on the north and west sides of the building as these rooms operate at a lower temperature and will provide a buffer space for the rest of the building.

The following graph shows the floor areas provided with windows that face either south or east in comparison with those that face west or north.

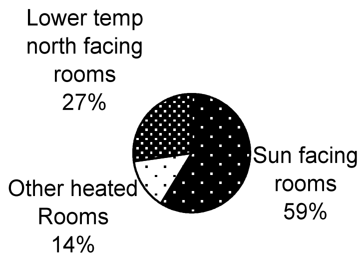

Fig 6. % of heated area with sun-facing glazing.

Note that the 27% figure includes the GP room and circulation that will be run at a lower temperature than the sun facing rooms (classrooms). The building is therefore 94% optimised from this passive solar area calculation perspective.

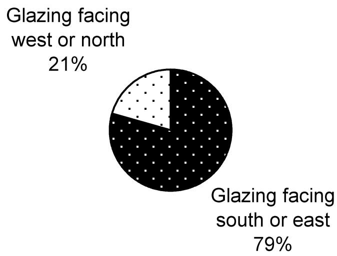

Fig 7. % of glazing facing the sun.

The graph above shows clearly that the school design is provided with a very strong passive solar weighting.

5.3 Typical School Sites

The design team considered the positioning and orientation of the building on various proposed school sites, often of restricted shape or topography, and this is one of the main reasons that a fully linear school with all classrooms facing south-east was not selected.

5.4 Entrances

The school as one of the main public buildings in communities prompted the need for clear way-finding to the main entrance, and also for child safety. Maintaining a prominent entrance resulted in two slight variations of the design, with main entrances to the north or south, to ensure that the passive solar orientation can still be optimised on almost any site. This strategy has proved very successful with optimum site layout and approach to main entrance achieved, while still optimising solar orientation, on 50 sites to date. These sites would be typical of available school sites, many less than ideal.

Fig 8. North Entrance with canopy.

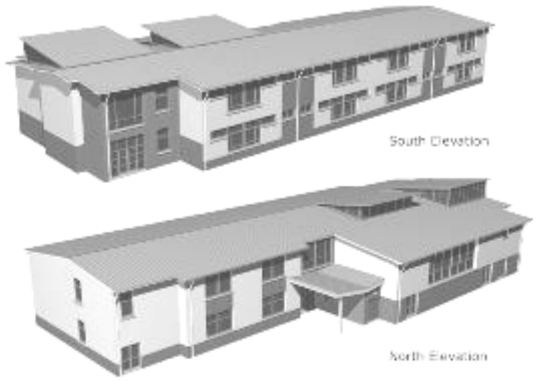

Fig 9. 3D model of 8 Classroom School with South & North Entrances.

6. Daylight

6.1 Principles

The CIBSE code for interior lighting design states that *"If electric lighting is not normally to be used during daytime hours, the average daylight factor should be not less than 5%"*

This statement takes no account of window orientation but later in the guide, during the detailed calculation section, it states that the daylight available to a south-facing window is 58% greater than for a north-facing window.

Following the calculation through, a south facing room with an average daylight factor of 5% could be used without additional artificial lighting for 80% of the working hours of 9.00am to 3.00pm, throughout the school year.

In addition to achieving a good average daylight factor, it is also important to achieve a good daylight distribution within the space. Control of sunlight glare on the southerly facing classrooms is an important issue. A sunlight simulation was done that indicated blinds are required to avoid glare within these rooms. These have worked successfully in use.

Fig 10. Typical Classroom demonstrating good daylight distribution.

6.2 Typical Classroom

The plot below indicates the results of the daylight analysis for a typical classroom. Classroom depths and glazing areas were optimised to provide a quality daylight distribution. The result indicate the average daylight factor is 5.2%, over a task area that excludes the rear corner computer area and the 600mm circulation/access strip at the storage area at the rear of the room. These confirm that the classrooms are provided with excellent daylighting. The high level windows in particular are giving a very good distribution of daylight to the rear of the room. In effect the improved distribution of daylight across the room provided by the high level windows would allow a lower acceptable average daylight factor within the room.

Fig 11. Typical Classroom windows.

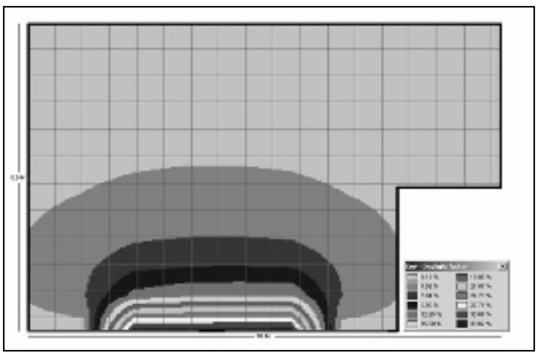

Fig 12. Typical Classroom Plan Daylight analysis.

The provision of south and east facing classrooms will generate a need for glare control during a number of hours during the year but any disadvantages of these orientations are

outweighed by the passive solar and daylight benefits provided.
Glare studies of the classrooms reveal that the upper glazing produces a glare spot on the blackboard and the lower glazing rarely affects the blackboard but will affect the children's desks. As the blackboard is more susceptible to glare than the seated area, upper windows 20% and lower view windows 50% light transmittance blinds were specified.

6.3 School Hall
An average daylight factor of 5.4% was achieved within this space. Balanced distribution is ensured by a north facing window screen together with a high level roof lantern at the rear of the space. These duplicate as openable windows to give very good cross ventilation for this high occupancy room. These results indicate that the school Hall is provided with excellent daylighting, and as windows are orientated north glare is also minimised for sports.

Fig 13. School Hall – balanced glare-free daylight from windows and high level roof lantern.

6.4 Artificial Lighting
Automatic occupant detection and daylight dimming controls are fitted to the high frequency, T5 lights to minimise the lighting loads. Within classrooms there are 2 zones across depth of space complementing the natural daylight.

7. Ventilation

7.1 Natural Ventilation
The building is naturally ventilated in all areas with the exception of the small area of a few internal toilets. All rooms are provided with single sided natural ventilation with the exception of the school hall that has cross ventilation by means of additional high-level roof windows. Classroom depths in particular have been minimised in order to maximise ventilation and daylight distribution. The natural ventilation scheme was optimised to produce quality, draught free ventilation by the careful positioning of openings. In classrooms, high level openings are provided to produce an even and draught-free distribution of air. Low level openings are also provided for rapid ventilation and warm weather. The total opening area required is that specified by the building regulations (5% of the floor area of each room). Passive vents are required for all rooms to the requirements laid out within the building regulations. With the level of ventilation provided and the window openings correctly distributed, overheating does not occur within the school. Ventilation flow rates have been calculated through the use of CFD simulation and are in excess of the required ventilation rates for occupant fresh air requirements.

8. Thermal Performance

8.1 Building Form
The use of a two storey building, and the relatively tight plan produced by nesting the school Hall between the two classroom blocks results in a relatively low external surface to floor area ratio. This relatively low area of exposed external surfaces results in less heat loss through the building fabric and also reduces services distribution route lengths.

8.2 Insulation
By way of ensuring longevity of the basic design, the first GRD schools constructed in 2005-6 were insulated to higher than the then required building regulation values. The GRD schools better the requirements of the current 2008 Building Regulations and even the more stringent 40% energy use reduction standards imposed by a few local authorities.

8.3 Air Leakage
Unwanted air leakage or infiltration during the night is responsible for approximately 50% of the buildings heating load, the specification for the GRD schools calls for an air tightness level of $5m^3/m^2/hr$ at 50Pa.
The first of the GRD schools to be completed easily achieved this target simply by specifying high density block work for the internal leaf of the cavity wall construction, sealed at window and roof cladding junctions.
The building smoke test revealed that the main sources of leakage were straightforward builders' items such as the sealing of service openings and a number of miss-aligned doors and windows. The 2 most recently completed schools (with junction detail improvements) achieved 3.5 and 3.1 $m^3/m^2/hr$ at 50Pa.
As a result of this the Department of Education and Science took a policy initiative that all new schools over 1,000 sq m be built to an air tightness level of $5m^3/m^2/hr$ at 50Pa. This is ahead of any building regulation requirements, and is another example of the Department's sustainable agenda commitment.

8.4 Heating
The main heat source for the schools, where natural gas is available, is fully condensing, fully modulating boilers. These boilers are provided with direct boiler temperature modulation in order to maximise the boilers efficiency. By providing direct boiler weather compensation, the water

temperature within the boilers can be held within the boilers condensing range for most of the heating season, without the need to oversize radiators. Biomass boilers are being piloted in one GRD school, as part of the Department of Education and Science ongoing research initiatives.

Individual room temperature control is by digital room sensors. These display the room temperature and allow the occupants to adjust it to a high degree of accuracy and certainty. Each sensor is provided with wall mounted instructions and recommended set points.

8.5 Water Usage

Water usage is minimised through automatic shut off taps and dual flush toilets. A direct gas fired water heater provides hot water. Local water blending valves are provided to reduce hot water usage. Water usage has been measured as 7 l/pupil/day, less than half of the CIBSE guide of 15 l/pupil/day.

Rain-water recovery, for toilet flush use only, is being piloted in several schools to confirm total installation costs, and assumptions on split of hand-wash versus flushing water use. Internal plumbing dual circuits and tank designs are available, and with site-specific drainage and storage tanks, overall costing can be prepared with cost analysis of water changes and payback periods. This is informing policy initiatives.

9. Monitoring

9.1 Metering

Meters are provided on the gas supply to the boilers and the water heater, and the main electrical power supply. These meters are linked to the principal's computer through the schools I.T. network, and can also be remotely monitored.

9.2 Control Systems

The first of the GRD schools which has been fitted with additional sensors and meters, and a remote monitoring interface for the controls system. Buildings are rarely commissioned for optimum performance due to the time taken to run seasonal commissioning tests on the building and optimise the control settings through gradual improvement. The remote monitoring system enables fine tuning of the control system. The information gathered can be used to set up the control systems in the all other GRD schools.

9.3 Energy Usage

Great care has been taken to optimise the energy performance of every aspect of the school, resulting in a design that uses less than 50% of the energy used by a school built to good international best practice CIBSE standards. The measured yearly energy usage is: Electrical 15kWh/m^2/yr, Heating 42 kWh/m^2/yr, a total of 57kWh/m^2/yr. The results of this formed the basis of the submission to the Sustainable Energy Ireland Awards 2007, where the GRD Schools Programme was highly commended.

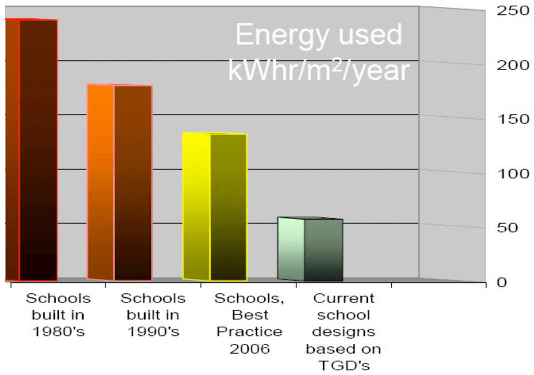

Fig 14. Energy usage in Irish Primary Schools.

10. Further Developments

10.1 Enhancing the design

To future proof the design, and by way of further development, improvements have been made to the building fabric insulation. U-values as follows: Walls 0.22, Ground Floor 0.21, Roofs 0.09, Window frame & glazing overall 1.9. These are estimated to result in a further improvement in heating energy usage of the order of 20%. It is the intention to monitor the energy usage of schools completed to these improved standards, with feedback into on-going research. This has already fed into the design of larger 24 and 32 classroom schools that function also as community centres. These are to start construction end 2008.

Fig 15. South & East facing classroom blocks with South Entrance between.

10. Conclusion

10.1 Overall Impact and Benchmark for Future

The overall energy impact of the design is considerable as 50 plus schools will be constructed to this proven and optimised, low energy design. Total value approximately €170m. The first 13 of these schools have already been built with 10 more currently on site, with 27 at advanced planning stages.

The generic prototype will be looked upon as the Department's benchmark for primary school accommodation for at least the next decade. As a proven low energy solution it will drive future research forward closer to zero or carbon neutral buildings. As schools within communities they have a wider educational role in environmental awareness, and demonstrate government commitment to a sustainable future.