

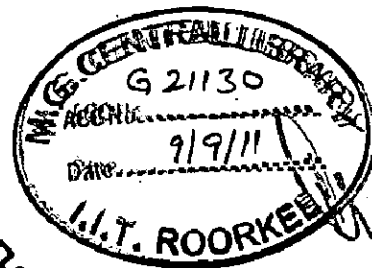
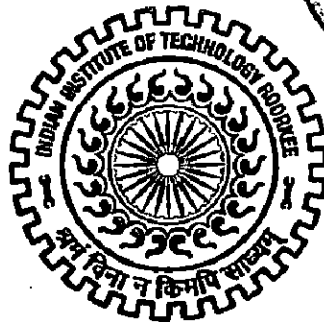
# ASSESSMENT OF LIGHTING IN SCHOOL BUILDINGS

A DISSERTATION

*Submitted in partial fulfillment of the  
requirements for the award of the degree  
of*  
MASTER OF ARCHITECTURE

By

**S. RAGHUNATH**



DEPARTMENT OF ARCHITECTURE AND PLANNING  
INDIAN INSTITUTE OF TECHNOLOGY ROORKEE  
ROORKEE -247 667 (INDIA)  
JUNE, 2011

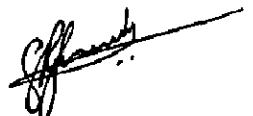
## CANDIDATE'S DECLARATION

I hereby declare that the work which has been presented in this dissertation entitled as 'ASSESSMENT OF LIGHTING DESIGN IN SCHOOL BUILDINGS' in partial fulfillment of the requirement for the award of the postgraduate degree of **MASTER OF ARCHITECTURE**, submitted in the Department of Architecture and planning, Indian Institute of Technology, Roorkee, is an authentic record of my own work carried out by me during the period from August 2010 to June 2011 under the supervision and guidance of Dr. Gaurav Raheja.

The matter embodied in this dissertation has not been submitted by me anywhere else for the award of any other degree elsewhere.

Date: 30<sup>th</sup> JUNE 2011


Place: Roorkee

  
(S. Raghunath)

---

## CERTIFICATE

This is to certify that the above statement made by the candidate **S. Raghunath** is correct to the best of my knowledge and belief.

  
**Dr. Gaurav Raheja**  
Assistant Professor,  
Department of Architecture and Planning,  
Indian Institute of Technology,  
Roorkee-247 667

## **ACKNOWLEDGMENT**

It would be an improper completion of this dissertation report on **“ASSESSMENT OF LIGHTING DESIGN IN SCHOOL BUILDINGS”**, without expressing my genuine appreciation for the assistance and support I received from various people.

Hence, I take this opportunity to express my heartfelt gratitude for the immense help and guidance I gained, to all those who were with me through the completion of this dissertation.

I convey my sincere gratitude to my guide Dr. Gaurav Raheja, Professor, Department of Architecture, for his timely comments and advice through all the stages of this research.

My heartfelt thankfulness to Professor S.Y Kulkarni, Department of Architecture, for his sincere guidance and support and also to Mr. Ashok Kumar, CBRI Roorkee, for being a source of encouragement.

I also thank all my teachers and staff of our department for their support and for providing me with all the facilities without which this research would have been incomplete.

I thank my parents and family members for the strength and support they have provided throughout the completion of this research.

And last, but not the least, I thank God for his blessings.

## **ABSTRACT**

It is a well known fact that lighting plays a very important role in the performance of any task in a space. Source of light can either be artificial or the sun. School buildings are a type of construction in which the occupants use it the most at the times when natural light is available in plenty. In a learning environment, the lighting plays a very major role. The aim of this thesis was to study about the lighting requirements of school buildings by performing a comparative analysis of school buildings in composite type of climate. For the purpose of this dissertation, the spaces that were studied were limited to laboratories and classrooms alone.

Building codes specify the average illumination levels required in a space according to the type of function that particular space will host. But case studies reveal that although average illumination levels may be within the recommended range, the actual level of illumination at individual positions in the observed space may be too high or too low in the same space, i.e. there is a large variation in the distribution of lighting in the space. This distribution of light is affected by several architectural parameters that can be controlled by the architect through the design process. This may be done for projects that have to be designed from the scratch, or for projects that need retrofits to control the illumination levels inside the space.

The final outcome of the dissertation consists of design guidelines for the spaces observed, based on the analysis of findings from the live case study and the literature review. The design guidelines deal with the main architectural parameters that have a direct impact on the indoor light quality.

## **LIST OF FIGURES**

### **CHAPTER 3 – LIBRARY CASE STUDIES**

<b>3.1. WORLD'S END SCHOOL</b>	<b>18</b>
<b>3.2. GROUND FLOOR PLAN FOR WORLD'S END SCHOOL</b>	<b>19</b>
<b>3.3. SECTIONS FOR WORLD'S END SCHOOL</b>	<b>20</b>
<b>3.4. CIRCULATION SPACE AND SPORTS HALL IN WORLD'S END SCHOOL</b>	<b>20</b>
<b>3.5. DESIGN CONCEPT, RIVERHEAD SCHOOL</b>	<b>21</b>
<b>3.6. BUILDING PLAN AND SECTIONS OF RIVERHEAD SCHOOL</b>	<b>22</b>
<b>3.7 SUTTON ELEMENTARY SCHOOL</b>	<b>23</b>
<b>3.8. AUDITORIUM OF SUTTON ELEMENTARY SCHOOL</b>	<b>24</b>
<b>3.9. CLASSROOM OF SUTTON ELEMENTARY SCHOOL</b>	<b>24</b>
<b>3.10. PLAN AND SECTION OF SUTTON ELEMENTARY SCHOOL</b>	<b>25</b>
<b>3.11. LIBRARY IN SUTTON ELEMENTARY SCHOOL</b>	<b>25</b>
<b>3.12. CENTRAL ROOM, ELEMENTARY SCHOOL AND AREA HIGH SCHOOL</b>	<b>26</b>
<b>3.13. INDIRECT LIGHTING IN ELEMENTARY SCHOOL AND AREA HIGH SCHOOL</b>	<b>27</b>
<b>3.14. CONNECTING LOBBY IN ELEMENTARY SCHOOL AND AREA HIGH SCHOOL</b>	<b>27</b>
<b>3.1. PLAN OF ELEMENTARY SCHOOL AND AREA HIGH SCHOOL</b>	<b>28</b>
<b>3.2. SECTION OF ELEMENTARY SCHOOL AND AREA HIGH SCHOOL</b>	<b>28</b>
<b>3.3. PIERREFONDS COMPREHENSIVE HIGH SCHOOL</b>	<b>29</b>
<b>3.18. AXONOMETRIC STUDY OF SYSTEMS IN PIERREFONDS COMPREHENSIVE HIGH SCHOOL</b>	<b>30</b>
<b>3.19. PRECAST CONCRETE CHANNELS IN PIERREFONDS COMPREHENSIVE HIGH SCHOOL</b>	<b>30</b>
<b>3.20. PLAN AND SECTION OF PIERREFONDS COMPREHENSIVE HIGH SCHOOL</b>	<b>31</b>

### **CHAPTER 4 – RESULTS AND DISCUSSIONS**

<b>4. SCHOOL BUILDING, WITH RECESSED WINDOWS</b>	<b>33</b>
<b>4.1.1. SCHOOL 1 TYPE 1 CLASSROOM PLAN</b>	<b>34</b>
<b>4.1.2. CEILING PLAN SHOWING FIXTURES IN TYPE 1 CLASSROOM</b>	<b>34</b>
<b>4.1.3. TYPES OF WINDOWS USED IN TYPE 1 CLASSROOM</b>	<b>34</b>

<b>4.1.4. EXTERIOR WALL FACADE ON WINDOW SIDES OF TYPE 1 CLASSROOM</b>	<b>35</b>
<b>4.1.5. TYPE 1 CLASSROOM IMAGE</b>	<b>36</b>
<b>4.1.6. SCHOOL 1 TYPE 2 CLASSROOM PLAN</b>	<b>37</b>
<b>4.1.7. CEILING PLAN SHOWING FIXTURES IN TYPE 2 CLASSROOM</b>	<b>37</b>
<b>4.1.8. TYPES OF WINDOWS USED IN TYPE 2 CLASSROOM</b>	<b>37</b>
<b>4.1.9. EXTERIOR WALL FACADE ON WINDOW SIDES OF TYPE 2 CLASSROOM</b>	<b>38</b>
<b>4.1.10. TYPE 2 CLASSROOM IMAGE</b>	<b>39</b>
<b>4.1.12. SCHOOL 1 TYPE 3 CLASSROOM PLAN</b>	<b>40</b>
<b>4.1.5. CEILING PLAN SHOWING FIXTURES IN TYPE 3 CLASSROOM</b>	<b>40</b>
<b>4.1.14. TYPES OF WINDOWS USED IN TYPE 3 CLASSROOM</b>	<b>40</b>
<b>4.1.15. EXTERIOR WALL FACADE ON WINDOW SIDES OF TYPE 3 CLASSROOM</b>	<b>41</b>
<b>4.1.16. TYPE 3 CLASSROOM IMAGE</b>	<b>42</b>
<b>4.1.17. SCHOOL 1 TYPE 4 CLASSROOM PLAN</b>	<b>43</b>
<b>4.1.6 CEILING PLAN SHOWING FIXTURES IN TYPE 4 CLASSROOM</b>	<b>43</b>
<b>4.1.19 TYPES OF WINDOWS USED IN TYPE 4 CLASSROOM</b>	<b>43</b>
<b>4.1.20. EXTERIOR WALL FACADE ON WINDOW SIDES OF TYPE 4 CLASSROOM</b>	<b>44</b>
<b>4.1.21. TYPE 4 CLASSROOM IMAGE</b>	<b>45</b>
<b>4.1.22. SCHOOL 1 TYPE 5 CLASSROOM PLAN</b>	<b>46</b>
<b>4.1.23. CEILING PLAN SHOWING FIXTURES IN TYPE 5 CLASSROOM</b>	<b>46</b>
<b>4.1.24. TYPES OF WINDOWS USED IN TYPE 5 CLASSROOM</b>	<b>46</b>
<b>4.1.25. EXTERIOR WALL FACADE ON WINDOW SIDES OF TYPE 5 CLASSROOM</b>	<b>47</b>
<b>4.1.26. TYPE 5 CLASSROOM IMAGE</b>	<b>48</b>
<b>4.1.27. SCHOOL 1 TYPE 6 CLASSROOM PLAN</b>	<b>49</b>
<b>4.1.28. CEILING PLAN SHOWING FIXTURES IN TYPE 6 CLASSROOM</b>	<b>49</b>
<b>4.1.29 TYPES OF WINDOWS USED IN TYPE 6 CLASSROOM</b>	<b>49</b>
<b>4.1.30. EXTERIOR WALL FACADE ON WINDOW SIDES OF TYPE 6 CLASSROOM</b>	<b>50</b>
<b>4.1.31. TYPE 6 CLASSROOM IMAGE</b>	<b>51</b>
<b>4.1.32. SCHOOL 1 TYPE 1 LABORATORY FLOOR PLAN</b>	<b>52</b>
<b>4.1.33. CEILING PLAN SHOWING FIXTURES IN TYPE 1 LABORATORY</b>	<b>52</b>

<b>4.1.34. TYPES OF WINDOWS USED IN TYPE 1 LABORATORY</b>	<b>52</b>
<b>4.1.35. EXTERIOR WALL FACADE ON WINDOW SIDES OF TYPE 1 LABORATORY</b>	<b>53</b>
<b>4.1.36. TYPE 1 LABORATORY IMAGE</b>	<b>54</b>
<b>4.2.1. SCHOOL 2 TYPE 1 CLASSROOM FLOOR PLAN</b>	<b>55</b>
<b>4.2.2. CEILING PLAN SHOWING FIXTURES IN TYPE 1 CLASSROOM</b>	<b>55</b>
<b>4.2.3. TYPES OF WINDOWS USED IN TYPE 1 CLASSROOM</b>	<b>55</b>
<b>4.2.4. EXTERIOR WALL FACADE ON WINDOW SIDES OF TYPE 1 CLASSROOM</b>	<b>56</b>
<b>4.2.5. TYPE 1 CLASSROOM IMAGE</b>	<b>57</b>
<b>4.2.6. SCHOOL 2 TYPE 2 CLASSROOM FLOOR PLAN</b>	<b>58</b>
<b>4.2.7. CEILING PLAN SHOWING FIXTURES IN TYPE 2 CLASSROOM</b>	<b>58</b>
<b>4.2.8. TYPES OF WINDOWS USED IN TYPE 2 CLASSROOM</b>	<b>58</b>
<b>4.2.9. EXTERIOR WALL FACADE ON WINDOW SIDES OF TYPE 2 CLASSROOM</b>	<b>59</b>
<b>4.2.10. TYPE 2 CLASSROOM IMAGE</b>	<b>60</b>
<b>4.2.11. SCHOOL 2 TYPE 1 LABORATORY FLOOR PLAN</b>	<b>61</b>
<b>4.2.12. CEILING PLAN SHOWING FIXTURES IN TYPE 1 LABORATORY</b>	<b>61</b>
<b>4.2.13. TYPES OF WINDOWS USED IN TYPE 1 LABORATORY</b>	<b>61</b>
<b>4.2.14. EXTERIOR WALL FACADE ON WINDOW SIDES OF TYPE 1 LABORATORY</b>	<b>62</b>
<b>4.2.15. TYPE 1 LABORATORY IMAGE</b>	<b>63</b>
<b>4.2.16. SCHOOL 2 TYPE 2 LABORATORY FLOOR PLAN</b>	<b>64</b>
<b>4.2.17. CEILING PLAN SHOWING FIXTURES IN TYPE 2 LABORATORY</b>	<b>64</b>
<b>4.2.18. TYPES OF WINDOWS USED IN TYPE 2 LABORATORY</b>	<b>64</b>
<b>4.2.19. EXTERIOR WALL FACADE ON WINDOW SIDES OF TYPE 2 LABORATORY</b>	<b>65</b>
<b>4.2.20. TYPE 2 LABORATORY IMAGE</b>	<b>66</b>
<b>4.3.1. SCHOOL 3 TYPE 1 CLASSROOM FLOOR PLAN</b>	<b>67</b>
<b>4.3.2. CEILING PLAN SHOWING FIXTURES IN TYPE 1 CLASSROOM</b>	<b>67</b>
<b>4.3.3. TYPES OF WINDOWS USED IN TYPE 1 CLASSROOM</b>	<b>67</b>
<b>4.3.4. EXTERIOR WALL FACADE ON WINDOW SIDES OF TYPE 1 CLASSROOM</b>	<b>68</b>
<b>4.3.5. TYPE 1 CLASSROOM IMAGE</b>	<b>69</b>
<b>4.3.6. SCHOOL 3 TYPE 2 CLASSROOM FLOOR PLAN</b>	<b>70</b>

<b>4.3.7. CEILING PLAN SHOWING FIXTURES IN TYPE 2 CLASSROOM</b>	<b>70</b>
<b>4.3.8. TYPES OF WINDOWS USED IN TYPE 2 CLASSROOM</b>	<b>70</b>
<b>4.3.9. EXTERIOR WALL FACADE ON WINDOW SIDES OF TYPE 2 CLASSROOM</b>	<b>71</b>
<b>4.3.10. TYPE 2 CLASSROOM IMAGE</b>	<b>72</b>
<b>4.3.11. SCHOOL 3 TYPE 3 CLASSROOM FLOOR PLAN</b>	<b>73</b>
<b>4.3.12. CEILING PLAN SHOWING FIXTURES IN TYPE 3 CLASSROOM</b>	<b>73</b>
<b>4.3.13. TYPES OF WINDOWS USED IN TYPE 3 CLASSROOM</b>	<b>73</b>
<b>4.3.14. EXTERIOR WALL FACADE ON WINDOW SIDES OF TYPE 3 CLASSROOM</b>	<b>74</b>
<b>4.3.15. TYPE 3 CLASSROOM IMAGE</b>	<b>75</b>
<b>4.3.16. SCHOOL 3 TYPE 4 CLASSROOM FLOOR PLAN</b>	<b>76</b>
<b>4.3.17. CEILING PLAN SHOWING FIXTURES IN TYPE 4 CLASSROOM</b>	<b>76</b>
<b>4.3.18. TYPES OF WINDOWS USED IN TYPE 4 CLASSROOM</b>	<b>76</b>
<b>4.3.19. EXTERIOR WALL FACADE ON WINDOW SIDES OF TYPE 4 CLASSROOM</b>	<b>77</b>
<b>4.3.20. TYPE 4 CLASSROOM IMAGE</b>	<b>78</b>
<b>4.3.21. SCHOOL 3 TYPE 1 LABORATORY FLOOR PLAN</b>	<b>79</b>
<b>4.3.22. CEILING PLAN SHOWING FIXTURES IN TYPE 1 LABORATORY</b>	<b>79</b>
<b>4.3.23. TYPES OF WINDOWS USED IN TYPE 1 LABORATORY</b>	<b>79</b>
<b>4.3.24. EXTERIOR WALL FACADE ON WINDOW SIDES OF TYPE 1 LABORATORY</b>	<b>80</b>
<b>4.3.25. TYPE 1 LABORATORY IMAGE</b>	<b>81</b>
<b>4.3.26. SCHOOL 3 TYPE 2 LABORATORY FLOOR PLAN</b>	<b>82</b>
<b>4.3.27. CEILING PLAN SHOWING FIXTURES IN TYPE 2 LABORATORY</b>	<b>82</b>
<b>4.3.28. TYPES OF WINDOWS USED IN TYPE 2 LABORATORY</b>	<b>82</b>
<b>4.3.29. EXTERIOR WALL FACADE ON WINDOW SIDES OF TYPE 2 LABORATORY</b>	<b>83</b>
<b>4.3.30. TYPE 2 LABORATORY IMAGE</b>	<b>84</b>
<b>4.4.1. SCHOOL 4 TYPE 1 CLASSROOM FLOOR PLAN</b>	<b>85</b>
<b>4.4.2. CEILING PLAN SHOWING FIXTURES IN TYPE 1 CLASSROOM</b>	<b>85</b>
<b>4.4.3. TYPE OF WINDOW USED IN TYPE 1 CLASSROOM</b>	<b>85</b>
<b>4.4.4. EXTERIOR WALL FACADE ON WINDOW SIDES OF TYPE 1 CLASSROOM</b>	<b>86</b>
<b>4.4.5. TYPE 1 CLASSROOM IMAGE</b>	<b>87</b>



<b>4.4.6. SCHOOL 4 TYPE 2 CLASSROOM FLOOR PLAN</b>	<b>88</b>
<b>4.4.7. CEILING PLAN SHOWING FIXTURES IN TYPE 2 CLASSROOM</b>	<b>88</b>
<b>4.4.8. TYPE OF WINDOW USED IN TYPE 2 CLASSROOM</b>	<b>88</b>
<b>4.4.9. EXTERIOR WALL FACADE ON WINDOW SIDES OF TYPE 2 CLASSROOM</b>	<b>89</b>
<b>4.4.10. TYPE 2 CLASSROOM IMAGE</b>	<b>90</b>
<b>4.4.11. SCHOOL 4 TYPE 1 LABORATORY FLOOR PLAN</b>	<b>91</b>
<b>4.4.12. CEILING PLAN SHOWING FIXTURES IN TYPE 1 LABORATORY</b>	<b>91</b>
<b>4.4.13. TYPE OF WINDOW USED IN TYPE 1 LABORATORY</b>	<b>91</b>
<b>4.4.14. EXTERIOR WALL FACADE ON WINDOW SIDES OF TYPE 1 LABORATORY</b>	<b>92</b>
<b>4.4.15. TYPE 1 LABORATORY IMAGE</b>	<b>93</b>
<b>4.4.16. SCHOOL 4 TYPE 2 LABORATORY FLOOR PLAN</b>	<b>94</b>
<b>4.4.17. CEILING PLAN SHOWING FIXTURES IN TYPE 2 LABORATORY</b>	<b>94</b>
<b>4.4.18. TYPE OF WINDOW USED IN TYPE 2 LABORATORY</b>	<b>94</b>
<b>4.4.19. EXTERIOR WALL FACADE ON WINDOW SIDES OF TYPE 2 LABORATORY</b>	<b>95</b>
<b>4.4.20. TYPE 2 LABORATORY IMAGE</b>	<b>96</b>
<b>4.5.1. SCHOOL 1 CLASSROOM 1 FLOOR PLAN</b>	<b>98</b>
<b>4.5.2. SCHOOL 1 CLASSROOM 5 FLOOR PLAN</b>	<b>98</b>
<b>4.5.3. SCHOOL 1 CLASSROOM 6 FLOOR PLAN</b>	<b>99</b>
<b>4.5.4. SCHOOL 1 LABORATORY PLAN</b>	<b>99</b>
<b>4.5.5. SCHOOL 2 CLASSROOM PLAN</b>	<b>100</b>
<b>4.5.6. SCHOOL 2 LABORATORY PLAN</b>	<b>100</b>
<b>4.5.7. SCHOOL 3 CLASSROOM PLAN</b>	<b>101</b>
<b>4.5.8. SCHOOL 3 LABORATORY PLAN</b>	<b>101</b>
<b>4.5.9. SCHOOL 4 CLASSROOM PLAN</b>	<b>102</b>
<b>4.5.10. SCHOOL 4 LABORATORY 1 PLAN</b>	<b>102</b>
<b>4.5.11. SCHOOL 4 LABORATORY 2 FLOOR PLAN</b>	<b>102</b>
<b>4.6.1. ELEVATIONS OF DIFFERENT TYPES OF WINDOWS USED IN CLASSROOMS IN SCHOOL 1</b>	<b>105</b>
<b>4. 6.2. ELEVATIONS OF WINDOW USED IN LABORATORIES IN SCHOOL 1</b>	<b>105</b>

<b>4.6.3. ELEVATIONS OF DIFFERENT TYPES OF WINDOWS USED IN CLASSROOMS AND LABORATORIES IN SCHOOL 2</b>	<b>106</b>
<b>4.6.4. LABORATORY AND CLASSROOM ILLUMINATION IN SCHOOL 2</b>	<b>106</b>
<b>4.6.5. ELEVATION OF WINDOW IN SCHOOL 3</b>	<b>107</b>
<b>4.6.6. BAMBOO STRIP SHADING USED IN SCHOOL 3</b>	<b>107</b>
<b>4.6.7. CLASSROOM IMAGES IN SCHOOL 3</b>	<b>107</b>
<b>4.6.8. TYPES OF WINDOWS USED IN CLASSROOMS AND LABORATORIES IN SCHOOL 4</b>	<b>108</b>
<b>4.6.9. ILLUMINATION IN LABORATORIES 1 AND 2 IN SCHOOL 4</b>	<b>108</b>
<b>4.7.1. ILLUMINATION GRAPH FOR SCHOOL 1</b>	<b>110</b>
<b>4.7.2. ILLUMINATION GRAPH FOR SCHOOL 2</b>	<b>111</b>
<b>4.7.3. ILLUMINATION GRAPH FOR SCHOOL 3</b>	<b>112</b>
<b>4.7.4. ILLUMINATION GRAPH FOR SCHOOL 4</b>	<b>113</b>
<b>4.8.1. ORIENTATION OF OBSERVED SPACES IN SCHOOL 1</b>	<b>114</b>
<b>4.8.2. ORIENTATION OF OBSERVED SPACES IN SCHOOL 2</b>	<b>115</b>
<b>4.8.3. ORIENTATION OF OBSERVED SPACES IN SCHOOL 3</b>	<b>116</b>
<b>4.8.4. ORIENTATION OF OBSERVED SPACES IN SCHOOL 4</b>	<b>117</b>
<b><u>CHAPTER 5 – CONCLUSIONS AND RECOMMENDATIONS</u></b>	
<b>5.1. ORIENTATION</b>	<b>118</b>
<b>5.2. PLAN FORM</b>	<b>119</b>
<b>5.3. SURFACE TREATMENT</b>	<b>120</b>
<b>5.4. APPLICATION OF LIGHT SHELVES</b>	<b>121</b>

## **LIST OF TABLES**

### **CHAPTER 2 – LITERATURE STUDY**

<b>TABLE 2.1. NUMBER OF POINTS FOR MEASURING ILLUMINANCE</b>	<b>16</b>
<b>TABLE 2.2. CORRECTION FACTORS FOR LUX METERS</b>	<b>17</b>

### **CHAPTER 3 – LIBRARY CASE STUDIES**

<b>TABLE 3.1 COMPARISION CHART</b>	<b>32</b>
------------------------------------	-----------

### **CHAPTER 4 – RESULTS AND DISCUSSIONS**

<b>TABLE 4.1.1. ILLUMINANCE LEVELS FOR TYPE 1 CLASSROOM IN SCHOOL 1</b>	<b>36</b>
<b>TABLE 4.1.2. ILLUMINANCE LEVELS FOR TYPE 2 CLASSROOM IN SCHOOL 1</b>	<b>39</b>
<b>TABLE 4.1.3 ILLUMINANCE LEVELS FOR TYPE 3 CLASSROOM IN SCHOOL 1</b>	<b>42</b>
<b>TABLE 4.1.4. ILLUMINANCE LEVELS FOR TYPE 4 CLASSROOM IN SCHOOL 1</b>	<b>45</b>
<b>TABLE 4.1.5. ILLUMINANCE LEVELS FOR TYPE 5 CLASSROOM IN SCHOOL 1</b>	<b>48</b>
<b>TABLE 4.1.6. ILLUMINANCE LEVELS FOR TYPE 6 CLASSROOM IN SCHOOL 1</b>	<b>51</b>
<b>TABLE 4.1.7. ILLUMINANCE LEVELS FOR TYPE 1 LABORATORY IN SCHOOL 1</b>	<b>54</b>
<b>TABLE 4.2.1. ILLUMINANCE LEVELS FOR TYPE 1 CLASSROOM IN SCHOOL 2</b>	<b>57</b>
<b>TABLE 4.2.2. ILLUMINANCE LEVELS FOR TYPE 2 CLASSROOM IN SCHOOL 2</b>	<b>60</b>
<b>TABLE 4.2.3 ILLUMINANCE LEVELS FOR TYPE 1 LABORATORY IN SCHOOL 2</b>	<b>63</b>
<b>TABLE 4.2.4 ILLUMINANCE LEVELS FOR TYPE 2 LABORATORY IN SCHOOL 2</b>	<b>66</b>
<b>TABLE 4.3.1. ILLUMINANCE LEVELS FOR TYPE 1 CLASSROOM IN SCHOOL 3</b>	<b>69</b>
<b>TABLE 4.3.2 ILLUMINANCE LEVELS FOR TYPE 2 CLASSROOM IN SCHOOL 3</b>	<b>72</b>
<b>TABLE 4.3.3 ILLUMINANCE LEVELS FOR TYPE 3 CLASSROOM IN SCHOOL 3</b>	<b>75</b>
<b>TABLE 4.3.4. ILLUMINANCE LEVELS FOR TYPE 4 CLASSROOM IN SCHOOL 3</b>	<b>78</b>
<b>TABLE 4.3.5. ILLUMINANCE LEVELS FOR TYPE 1 LABORATORY IN SCHOOL 3</b>	<b>81</b>
<b>TABLE 4.3.6. ILLUMINANCE LEVELS FOR TYPE 2 LABORATORY IN SCHOOL 3</b>	<b>84</b>
<b>TABLE 4.4.1. ILLUMINANCE LEVELS FOR TYPE 1 CLASSROOM IN SCHOOL 4</b>	<b>87</b>
<b>TABLE 4.4.2. ILLUMINANCE LEVELS FOR TYPE 2 CLASSROOM IN SCHOOL 4</b>	<b>90</b>
<b>TABLE 4.4.3. ILLUMINANCE LEVELS FOR TYPE 1 LABORATORY IN SCHOOL 4</b>	<b>93</b>
<b>TABLE 4.4.4. ILLUMINANCE LEVELS FOR TYPE 2 LABORATORY IN SCHOOL 4</b>	<b>96</b>

<b>TABLE 4.5.1. CLASSROOM DIMENSIONS</b>	<b>97</b>
<b>TABLE 4.5.2. LABORATORY DIMENSIONS</b>	<b>97</b>
<b>TABLE 4.6.1. WINDOW TO FLOOR AREA RATIO FOR CLASSROOMS</b>	<b>104</b>
<b>TABLE 4.6.2. WINDOW TO FLOOR AREA RATIO FOR LABORATORIES</b>	<b>104</b>
<b>TABLE 4.7.1. AVERAGE ILLUMINATION TABLE FOR CLASSROOMS</b>	<b>109</b>
<b>TABLE 4.7.2. AVERAGE ILLUMINATION TABLE FOR LABORATORIES</b>	<b>109</b>

## CONTENTS

CANDIDATE'S DECLARATION	i
ACKNOWLEDGEMENT	ii
ABSTRACT	iii
LIST OF FIGURES	iv
LIST OF TABLES	x
1 CHAPTER 1 - INTRODUCTION .....	3
1.1 LIGHT .....	3
1.2 LIGHTING DESIGN .....	3
1.3 NEED TO STUDY LIGHTING .....	3
1.4 AIM.....	4
1.5 OBJECTIVES.....	4
1.6 SCOPE AND LIMITATION.....	4
1.7 RESEARCH METHODOLOGY .....	5
2 CHAPTER 2 - LITERATURE STUDY.....	7
2.1 PARAMETERS IN LIGHTING.....	7
2.2 ELEMENTS OF LIGHT .....	8
2.3 ENVIRONMENTAL OBJECTIVES AND HUMAN NEEDS .....	8
2.4 LIGHTING AND EYESIGHT .....	12
2.5 DESIGN OF LUMINOUS ENVIRONMENT .....	14
2.6 PRINCIPLE OF MEASUREMENT.....	15
3 CHAPTER 3 - LIBRARY CASE STUDIES.....	18
3.1 WORLD'S END SCHOOL, ENFIELD.....	18
3.2 RIVERHEAD SCHOOL, SEVENOAKS .....	21
3.3 SUTTON ELEMENTARY SCHOOL, MASSACHUSETTS .....	23
3.4 ELEMENTARY SCHOOL AND AREA HIGH SCHOOL, NEW HAMPSHIRE..	26
3.5 PIERREFONDS COMPREHENSIVE HIGH SCHOOL, QUEBEC .....	29
3.6 ANALYSIS .....	32
4 CHAPTER 4 - RESULTS AND DISCUSSIONS .....	33
4.1 OBSERVATIONS FOR SCHOOL 1 – ADARSH BAL NIKETAN SENIOR SECONDARY SCHOOL.....	34
4.2 OBSERVATIONS FOR SCHOOL 2 – FATHER AGNEL SCHOOL NOIDA.....	55

4.3	OBSERVATIONS FOR SCHOOL 3 – FATHER AGNEL SCHOOL NEW DELHI 67	
4.4	OBSERVATIONS FOR SCHOOL 4 – KERALA SCHOOL NEW DELHI .....	85
4.5	SPATIAL DIMENSIONS (IN MTS) .....	97
4.6	WINDOW TO FLOOR AREA RATIO.....	104
4.7	AVERAGE ILLUMINATION LEVELS.....	109
4.8	ANALYSIS .....	114
5	CHAPTER 5 - CONCLUSIONS AND RECOMMENDATIONS .....	118
5.1	INTRODUCTION .....	118
5.2	ORIENTATION .....	118
5.3	PLAN AND PLAN-FORM.....	119
5.4	FURNITURE.....	119
5.5	INDOOR SURFACE TREATMENT .....	120
5.6	FENESTRATION AND DETAILS .....	120
6	APPENDIX.....	123
7	BIBLIOGRAPHY .....	128

## **1 CHAPTER 1 - INTRODUCTION**

### **1.1 LIGHT**

It is a form of energy. It is what makes our surroundings visible to us. From a designer's point of view, it is one of the most powerful form-giving tools that are available to us. It is one of the main modes of expression of the architect.

In older days, the difference between an ordinary building and a great building was how much they could utilize the only source of light available back then, the sun. The structures were themselves adapted to create positive spatial effects. Today we have different artificial sources of light that we can control more effectively than daylight.

### **1.2 LIGHTING DESIGN**

It is a process that helps us to integrate light into the fabric of architecture. Lighting depends on the ability of our eyes to function with reasonable efficiency in a variety of conditions. Our eyes can use very low and very high levels of lighting but they function best in the presence of certain optimum conditions. The aim of good lighting design is to provide those optimum conditions. In most of the successful designs, it is first decided what is to be lit and how. Only then, the designer comes to what types of fixtures are to be taken into account for the same.

The human perception of space is not based on the quality of light entering the eye but rather the quantity of contrast. The brightness contrast of a place will determine the emotional impact of a place. The direction and distribution of light can be set to achieve the desired emotional settings via the brightness contrast.

Understanding the role of daylight is fundamental. But knowledge about different forms and properties of artificial lighting at night and day is also essential. Now it is considered impossible to consider daytime lighting of any building type without an integrated solution.

### **1.3 NEED TO STUDY LIGHTING**

Energy crisis demands much more emphasis than ever before on the use of natural agencies for lighting, heating and cooling of buildings. Although the expenditure on artificial lighting of buildings may be a small fraction of the total energy budget, especially because of commendable advancement in the field of luminous efficiency of light sources and low cost of electrical energy at present, yet daylighting will continue to be an important functional aspect of building design.

Research has proven that when case study was conducted in school buildings to measure the amount of illumination on the surfaces, it was seen that majority of the examples had insufficient light even by prescribed standards. (*Artificial Lighting in Classrooms Results of a Lighting Survey* - G. K. Cook, 1990) However, there is no documented evidence of any such study being conducted in the Indian context.

#### **1.4 AIM**

To perform a comparative analysis of different schools of composite climate on basis of lighting efficiency and derive design guidelines for the same.

#### **1.5 OBJECTIVES**

- To study about the lighting requirements of school buildings.
- To study and analyse lighting efficiency in different types of school buildings in composite climate.
- To derive the major factors that affect school buildings in terms of lighting efficiency.
- To develop guidelines for lighting efficiency in the design of school buildings

#### **1.6 SCOPE AND LIMITATION**

Institutional buildings are one of those building types in which lighting design plays an important role due to the nature of activities that occur inside them. People require constant stimuli to remain alert and sensitive, which can be achieved by lighting design, be it natural or artificial. Operational efficiency of lighting is another aspect to be considered. Most educational institutions are owned by private organizations and hence the energy consumption also matters to them. A balance has to be achieved in the lighting design process so that the scheme is effective in terms of illumination and operational costs as well. The integrated scheme can be a mix of daylighting and artificial lighting.

There are different components of an institutional building, all of which have different requirements where lighting is concerned. There are classrooms, laboratories, conference rooms, auditoriums, extra-curricular activity spaces, libraries, sick rooms, toilet blocks, transitional spaces and more such components in any institutional building. All these have different lighting requirements that must be considered by designer in the initial planning stage itself. The extent of study is limited to study of classrooms and laboratories in school buildings only. Schools were selected on the basis of certain architectural features that have an effect on the light quality.



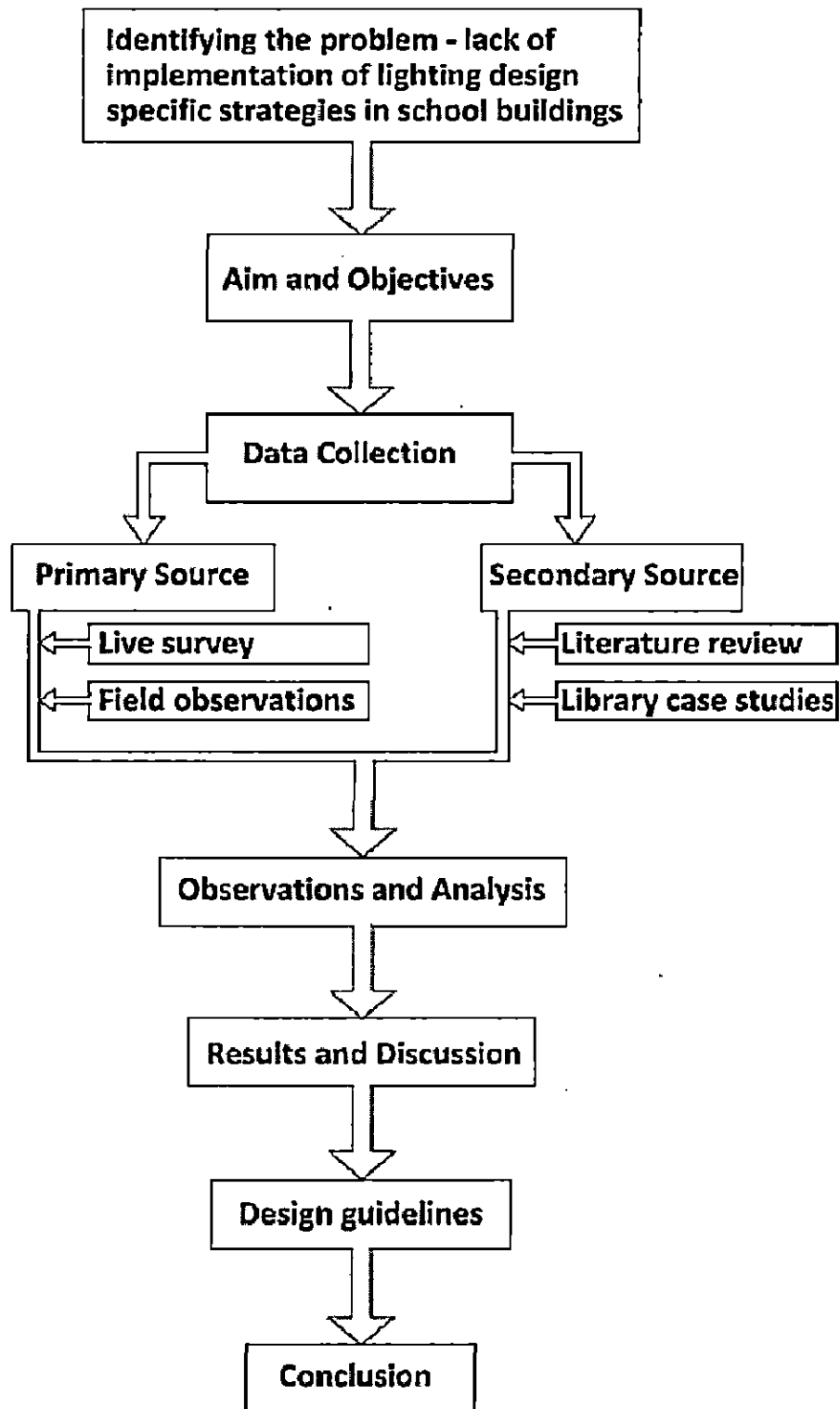
## 1.7 RESEARCH METHODOLOGY

The problem identified was the lack of implementation of lighting specific design strategies in school buildings. School buildings usually do not consider lighting as important factor that should influence design. Rather most schools just shoehorn some basic rules regarding fenestrations so that the lighting levels meet the recommended levels specified in the building codes.

To achieve the objectives stated above, the following steps will be taken sequentially.

- Literature study on basic theories of lighting and lighting design to understand the various parameters that affect quality of light inside any space and design of school buildings to understand the basic requirements of this building type.
- Literature study analysis helped to derive the architectural parameters that affect lighting of a space.
- Schools were selected for conducting live case study. These schools were located in composite climate zone as this particular climatic zone has extreme weather variations and would require the buildings to have provision for lighting in summer and winter.
- All selected schools were designed using grids and the space dimensions were similar for them. The plan form was also similar. School 1 was selected because it was the only example to use fenestrations in more than one wall. School 2 was selected because of the different plan form and different fenestration. School 3 was selected for the large window to floor area ratio and school 4 was selected for the different indoor finishes applied in similar plan.
- Live case study will help to understand how architectural parameters affect quality of light inside the observed space of the schools.
- The observations will be compiled and analyzed
- Design guidelines for the various architectural parameters will be derived on the basis of analysis of the observations from literature review and live case studies.

FLOWCHART OF WORK



## **2 CHAPTER 2 - LITERATURE STUDY**

### **2.1 PARAMETERS IN LIGHTING**

#### **2.1.1 BRIGHTNESS**

Brightness is a subjective quantity. It indicates the intensity of light on a given region of retina in certain time. This value is affected by the intensity of light falling on other regions of the retina (contrast). This value changes again if the retina has been subject to different intensity of light in the recent past (adaptation). Increasing sensitivity of eyes in low light is called Dark adaptation. It causes reduction in the ability to make out finer details of the luminous environment. The given amount of light in the space appears to become brighter. The brightness contrast of a space determines its' emotional impact.

A given region will appear brighter or darker if its surroundings are darker and lighter respectively. A given colour will appear to be more intense if it is surrounded by its' complementary colour.

#### **2.1.2 COLOUR PERCEPTION**

Brightness is function of colour. Colours in the middle of the spectrum look brighter than the colours at end. The visible spectrum of colours consists of Violet, Blue, Green, Yellow and Red. Spectral hues are formed by mixing of three colours of light and adjusting intensities. What appears as white is due to general illumination and not mix of colours. For example, a lit candle will appear to be white by itself and yellow in presence of daylight.

#### **2.1.3 LIGHTING AND ENVIRONMENTS**

There is large level of similarity in people's reaction to light. Lighting stimulation levels required are different for different activities. Complex, crowded and novel environments are high load lighting type environments. Complex tasks need high load lighting. *More stimuli from the environment can become distracting.* Simple, uncrowded and conventional environments are low load lighting type environments. Simple tasks benefit with ample stimulation.

Low contrast environments have low visual stimulation. They have largely diffused light and little of focused light. All parts of this environment have somewhat equal lighting emphasis. This type of environment is suitable for easy visual tasks, random circulation patterns and flexible relocation of work areas. However, forms are ill-defined in this environment. Perception of textures is also poor.

High contrast environments have high levels of visual stimulation. They consist largely of focus lighting and little part of diffuse lighting. Lighting levels are different for foreground and background. Attention is drawn towards lit areas that contrast with less lit areas. This environment is suited for circulation guiding. Lighting systems render lit and shaded patterns. Public space lighting incorporates light schemes with high facial clarity. This helps to reduce anonymity and bring people closer due to clarity of expression. Private space lighting incorporates light schemes with low facial clarity. This helps to bring about intimacy. Shadows and silhouettes add to the feeling of detachment and privacy.

Lighting can be used to alleviate monotony and lack of features by adding stimuli that vary with time or with activities. This can include lighting systems, surface finishes, textures, colors, etc.

Diffuse lighting reduces likelihood of flaws being visible. It also increases the smoothness in appearance of a surface. It reduces contrast of the object. Concentrated lighting adds contrast but reduces the visibility of detail.

## **2.2 ELEMENTS OF LIGHT**

Light is of three types – Ambient light, Focal light, Sparkle.

- Ambient light – it provides shadow-less illumination. It is relaxing and suggests infinity. It minimizes form and bulk in a space.
- Focal light – it helps to organize and gauge depth in a space. It is directive and sets precedence. It creates focal points.
- Sparkle – it heightens sensations and adds highlights. It has less area and magnitude of luminance. It can be direct type (with small light source and perforated shielding), reflected type (textured metal or pebbled surface) or transmitted type (as seen in frosted glass or crystal chandeliers)

Glare is excessive light coming from the wrong direction. It depends on direction of light, location of source, its intensity and area of luminance.

## **2.3 ENVIRONMENTAL OBJECTIVES AND HUMAN NEEDS**

Well lit environments helps people to do whatever task they want to do and also make them feel comfortable when they perform that task. The goal of lighting design for a space is to provide a comfortable, pleasant, interesting, functional and reassuring environment for the people who will inhabit that space.

A person feels comfortable when he/she is able to concentrate on the task that is at hand. This means that the required information to do that task is clearly visible and the background information of the luminous environment doesn't distract from that task. When distraction does happen, it makes the task uncomfortable for the user. A luminous environment that gives the required information easily is more desirable than one that doesn't do so.

### **2.3.1 BIOLOGICAL NEED FOR VISUAL INFORMATION**

Human perception is an active information seeking process that involves many mechanisms in the eye and the brain, simultaneously, consciously and otherwise. Perception is a selective process. A person's attention is automatically drawn towards the visual elements that will provide the necessary information that is needed for performing their conscious activities. One requirement of a good luminous environment is that it should make readily perceptible that information which is needed by a person's conscious and voluntary activities.

Involuntary attention of immediate sensorial sort has either very intense, sudden or voluminous stimulus or an instinctive stimulus that appeals to one's normal congenital impulses by it's' nature itself.

When one is fully concentrating upon a demanding task, he/she becomes relatively unconcerned about other factors. Irrelevant visual information may become distracting as well. When formal tasks need less focus, the focus of perception will look for information to sate the biological needs.

*"...Type of motivation to which perception is most directly related is the necessity of maintaining contact with the environment and adapting behavior to environment change.*

*The perception capacities seem to function in such a manner as to produce rapid reaction to change, whereas in an unchanging atmosphere, they may cease to operate effectively..."*

M.C.Vernon, *Perception through Experience*

Objects that are relatively bright on contrast with respect to their environment, background, etc. automatically attract attention. Luminous environment in which biologically necessary information is unavailable, is distorted, confused or overpowered, invoke feeling of discomfort and dissatisfaction. Visual perception involves much more than the eye alone. Seeing invokes the brain as well as the eye. The brain plays a major role in determining what characteristics of objects make them worthy of attention, based on prior experience. Brain constantly monitors the luminous environment for new information relevant to biological or

activity needs, unexpected things become 'figures' to the visual processing system. It is not necessarily the strength of a particular quality, it may even be the absence of a quality that draws attention. Involuntary attention is influenced by contrast, context, prior experience and expectation.

Awareness must be there for –

- Location with regard to water, food, heat, sunlight, routes, etc.
- Time and environmental conditions that relate to the body clock.
- Weather, need for clothing, heating and cooling, shelter.
- Enclosure safety of structure, location and nature of environmental controls.
- Presence of other living things, flora, fauna, people.
- Territories, boundaries and personalization of space.
- Places of refuge, shelter in times of danger.
- Opportunities for relaxation and stimulation of mind, body and senses.

Changes in these important aspects of environment trigger warning signals in the brain and draw attention. One pays more attention to biologically important factors than to other sensory data that is not relevant.

### **2.3.2 NEED FOR ORIENTATION**

For protection of the body, awareness should be there about location, movement and state at all times. Sensory monitors give the required information even when one is asleep. Continuous visual information is needed for all physical activities like walking, running, working, etc.

Orientation is affected by prior experience and expectations. Our senses constantly receive raw data which is sorted out automatically with only relevant information being visible. The relevance is decided on basis of meaning, importance, during process of perception forming. Under different conditions, different information becomes appropriate.

### **2.3.3 TIME ORIENTATION**

This is another biological need that needs visual confirmation from the environment. Internal biological clocks adjust according to our senses to keep track of day and night. Because of time orientation, one expects it to be brighter outside than inside, in daytime and vice-versa in night time. The eye adapts to gradually changing luminous conditions during the cycle of day and night.

#### **2.3.4 CONSISTENCY BETWEEN LIGHT GRADIENTS AND STRUCTURAL FORMS**

People have definite expectations of three dimensional objects' appearance. This is by observation of light gradients and shadows that define form and volume. There are definite expectations of how most things (walls, floors, roofs, columns) should look when rendered in light. Uneven gradients of light seem pleasant when consistent with what one expects but can become disturbing and distracting if done so for no apparent reason.

#### **2.3.5 CONTACT WITH SUNLIGHT**

Visible sunlight gives important clues about the three dimensional form and orientation, indicating the state of weather. Designers always try to bring sunlight inside a building in such a way that it doesn't interfere with the functioning.

#### **2.3.6 NEED FOR OUTSIDE VIEWS**

Daylight becomes desirable because of illumination, spectral quality and views associated with it. North facing clear windows needs no solar controls. View through various types of sunscreens is not comfortable as there is competition between the elements on the glazing plane and the view beyond. It is undesirable to have translucent glazing on building façade as they block visual information about the exteriors. Glass blocks create interesting patterns but also distort light due to their prismatic nature. Glass curtain walled buildings without solar control have high solar heat load in summers and unpleasant radiant cooling in winters. They also experience high sky glare and shadows.

Role of windows in modern architecture needs to be examined in terms of optimizing views. With means of artificial illumination available today, size, shape and placement of windows can be looked into. Horizontal views should be seen through horizontal windows. Low buildings with high windows are considered good if there are good views all around. High rise buildings can have windows of restricted height. Skylights and clerestories must be glazed with clear glazing instead of translucent glazing.

#### **2.3.7 NEED FOR DIRECTIONAL SIGNS AND CLUES**

Good graphics are important in any complex environment. Shopping streets, government buildings, etc. would be incomprehensible without them. In an unfamiliar environment, it is helpful if perceptible patterns of visual information are consistent that they can be used for guidance.

### **2.3.8 FOCUS ON ACTIVITIES**

Lighting should be used to create order and relevance in the work environments, it should not create glare, visual noise and distracting, disturbing patterns. Elements of visual field that are retreated to the activity should be highlighted. Spaces for multiple activities should not focus on any one particular activity alone, but should provide understandable backgrounds that will allow users to choose a focus and concentrate on it without distraction.

## **2.4 LIGHTING AND EYESIGHT**

Raw data is fed to the eye as images that get converted into electrical impulses that are sent to the brain. These impulses are then sorted according to the experience filter. This is an attributive process of classification.

Immediate awareness of a stimulus is not necessarily the most important factor. It is a function of the associations that can be made in the experience filter and of the relevance of the stimulus to convert needs for environmental information. The meaning of the stimulus determines the relative importance.

### **2.4.1 EXPECTATIONS IN PROCESS OF PERCEPTION**

Once incoming data has been sorted out and classified, expectation comes into play. Expectations in connection with luminous environment design help in activities like finding one's way around. They are outputs in the process of perception and also influence the selection of sensory inputs.

### **2.4.2 AFFECTIVE COMPONENT OF PERCEPTION**

It deals with how the stimulus affects an individual's emotional or evaluative response to stimuli. Stimulus is assigned attributive classification. This will make certain emotional responses that finally determines how one feels in a given situation.

Attributive sets links to prior experience, activates expectations and invokes emotional responses. Expectations influence what next will the focus be upon and triggers varied emotions. Affective component determines how much importance is given to it.

### **2.4.3 FOCUS SELECTOR**

It dictated the scanning pattern of the eye. Under conscious control, the eye checks the luminous environment for significant changes that may need conscious attention. Focus selector then may target the stimuli related to biological needs for information. It is influenced by stored past information in form of attributive component, personal habits and expectations and the mental state of the perceiver.



#### **2.4.4 CENTRAL AND PERIPHERAL VISION**

The shape of the eye causes maximum sharpness of vision near a small area of the retina, called the fovea. The images forming here are in finer detail than on other parts of the retina. Central vision scans the luminous environment and gets detailed information about the visual field, where the focus selector directs it. Peripheral vision scans rest of the luminous environment for any change that may need the attention of the focus selector.

#### **2.4.5 DISTRACTION**

It is the interruption of normal sequence of consciously directed eye movements by the focus selector. A new stimulus is processed by the experience filter to see if it is important enough or not. If it is not, then the focus selector returns to the previous focus.

Distraction may relate to activities or biological needs. Activity related distraction can become useful. For example – when one writes on a blank piece of paper, one may write slanting without realizing immediately. It may be realized while writing and corrected again. Biological needs related distraction can become dangerous. For example – when one walks on a paved road, a glittering stimulus may indicate sharp glass and hence becomes relevant to the protection of the body.

#### **2.4.6 DISTRACTION BY LUMINOUS DOMINANCE**

The source of distraction may be very bright (Dominance of luminance). The eye contracts the iris to reduce the amount of light falling on the retina. This reduces the visibility of other objects in the visual field and can be potentially dangerous. Direct light sources invoke this reaction. If light source doesn't have any inherent interest or any useful function, the mind classifies it as visual noise or glare which is unpleasant.

The sun is not distracting despite its' high luminance (except when it is close to the eye-line) because it behaves consistently to one's expectations. The highlights and shadows created by sunlight are a constant source of orientation to its location. Similar fluorescent fixture of comparable luminance will become unpleasant and seem unnatural since the focus selector is constantly drawn towards it.

#### **2.4.7 DISTRACTION BY PATTERN DOMINANCE**

Strong patterns of visual information can dominate the visual field and demand attention of focus selector. This effect can be observed when one uses mirrored glass on building exterior and they reflect interior layout and overlay them on the view outside and make it seem confusing.

## 2.5 DESIGN OF LUMINOUS ENVIRONMENT

Conventional design processes are fragmented and compartmentalized. Usually decisions are made one at a time, usually in this sequence – planning – structure – mechanical systems – lighting – detailing – finishing.

Irreversible decisions made at the onset restrict options available to the design team. The end result is a luminous environment that shows nearly no variation through a project. They don't meet the biological and activity needs required of an environment.

The typical method to do lighting design for a space –

- Determining the required average level of illumination from the given lighting standards (may be a single level for a type of building)
- Selecting lighting fixtures to be mounted in the pre-selected ceiling system that is “highly economical and effective” at illuminating the work plane.
- Calculating the number of fixtures necessary to get the required levels of illumination
- Finding an appropriate layout for the required number of fixtures that will distribute light uniformly over the work plane.

Some restrictions are imposed to eliminate undesirable visual noise (glare from patterns of light fixtures) but they are mostly too restrictive to allow desirable, relevant high brightness elements such as pleasant window views. In school designs in particular, brightness restrictions have been used to eliminate windows and also to lower transmittance of window glass to such an extent that it ends up making the room seem dull and gloomy in sunny days also.

Visual Comfort Probability index rates the various arrangements of fixtures according to the proportion of viewers who find the arrangements tolerable from the point of view of glare. If VCP objective is 70%, it means that 70% of total occupants of that space should find glare conditions of that space acceptable. VCP rates only glare, it doesn't deal with the fact that HOW people are going to perceive that space (comfortable or pleasant or otherwise)

Equivalent Sphere Illumination is the degree of measure to which lighting installation approaches the effectiveness of sphere lighting. Spherical lighting causes very low loss of contrast due to veiling reflections. ESI rating indicates the level of illumination from spherical source that would be required to produce equivalent degree of accuracy in performing the visual task as lighting installation being evaluated.

ESI has its own restrictions –

It deals only with legibility of matter of given size in front of the reader. There is no guarantee that this task will be equally performed throughout the space.

It varies with location and orientation of the task. Average ESI is calculated. There is no available method to make a comparative evaluation of two alternative design options with different distributions of ESI. Measuring ESI is a costly and difficult process.

Similar qualitative criteria are Lighting Effectiveness Factor (LEF = ESI/ Illumination level of a task) and Contrast Rendition Factor (CRF – capability of lighting installation to render contrast between detail and contrast of a task.)

## 2.6 PRINCIPLE OF MEASUREMENT

- The efficiency of a light source is indicated by luminous efficacy, lm/Watt. Manufacturers usually give this value after testing the lamps at laboratories. It is difficult to establish the luminous efficacy value of lamps at site conditions.
- All the light emitted by the lamp does not reach the work area. Some light is absorbed by the luminaire, walls, floors & roof etc. The illuminance measured, in lumens/m<sup>2</sup> i.e. lux, indicates how much light i.e. lumens is available per sq. meter of the measurement plane.
- Target luminous efficacy (lm/Watts) of the light source is the ratio of lumens that can be made available at the work plane under best luminous efficacy of source, room reflectance, mounting height and the power consumption of the lamp circuit. Ideally, we would expect the target luminous efficacy to be available on the work plane.
- However, over a period of time the light output from the lamp gets reduced, room surfaces becomes dull, luminaires becomes dirty and hence the light available on the work plane deviates from the target value. The ratio of the actual luminous efficacy on the work plane and the target luminous efficacy at the work plane is the Installed Load Efficacy Ratio (ILER).
- A second aspect of efficiency of utilization is to take into account, the light available at task and non-task areas. Usually for commercial areas, the recommended illuminance at the non-task areas is at least one-third of the average task illuminance, while keeping a minimum illuminance required at the horizontal plane to be 20 lux. From illuminance measurements the ratio of illuminance at non task areas and task areas can be estimated to understand whether the non-task illuminance level is more than required or not.

### 2.6.1 METHOD OF MEASUREMENTS

The following parameters were measured.

- Illuminance levels
- Length & width of room,
- Mounting height of light fixtures

Lux meters corrected for V-lambda should be used for measurement of illuminance. The accuracy of 5% and suitable range up to 10000 lux should be used as per the BEE second draft code of lighting (2004)

### 2.6.2 DETERMINATION OF ILLUMINANCE MEASUREMENT POINTS

Based on the room index, the minimum number of illuminance measurement points is decided as per the following table 4.2.

Room index,  $RI = \frac{L \times W}{H_m}$

$$H_m \times (L+W)$$

Where L = Length

W = Width

$H_m$  = Height of the luminaires above the plane of measurement

Room index	Minimum number of measurement points	
	For $\pm 5\%$ accuracy	For $\pm 10\%$ accuracy
$RI < 1$	8	4
$1 < RI < 2$	18	9
$2 < RI < 3$	32	16
$RI > 3$	50	25

TABLE 2.1. NUMBER OF POINTS FOR MEASURING ILLUMINANCE

For a space having length  $L = 5\text{m}$ , width  $W = 5\text{m}$  and lamp mounting height of  $2.6\text{m}$ ,  $RI = 0.96$  i.e. there must be at least 8 measurement points for 5% accuracy and at least 4 for 10% accuracy. The measurement grid should be positioned to cover a representative area of the working plane.

**2.6.3 MEASUREMENT OF ILLUMINANCE**

- Defining the workspace where evaluation is to be done, in this case science laboratories and classrooms in schools
- Measuring the room length ‘L’, width ‘W’ and mounting height ‘Hm’
- Calculation of room index,  $RI = \frac{L \times W}{H_m \times (L+W)}$
- Based on Room Index, determining the minimum number of illuminance measurement points required and distributing these points evenly in the room.
- Measuring illuminance using a calibrated lux meter at each point. Calculating the average value of measured illuminance at all points. If E1, E2,..., En are illuminance measurements at points 1,2,..., n

Average illuminance,  $E_{av} = \frac{(E1+E2 +E3 + .....+ En)}{N}$  X correction factor

The correction factor is given in table for different types of lamps.

- Multiplying average illuminance with the area to get total luminous flux (lumens) incident on the measurement plane. Total available lumens on the measurement plane = Average illuminance X (L X W) i.e.  $\phi_m = E_{av} \times L \times W$

Light source	Correction factor
Mercury Lamp	X 1.05
Fluorescent Lamp	X 0.99
Sodium Lamp	X 1.11
Daylight	X 0.95

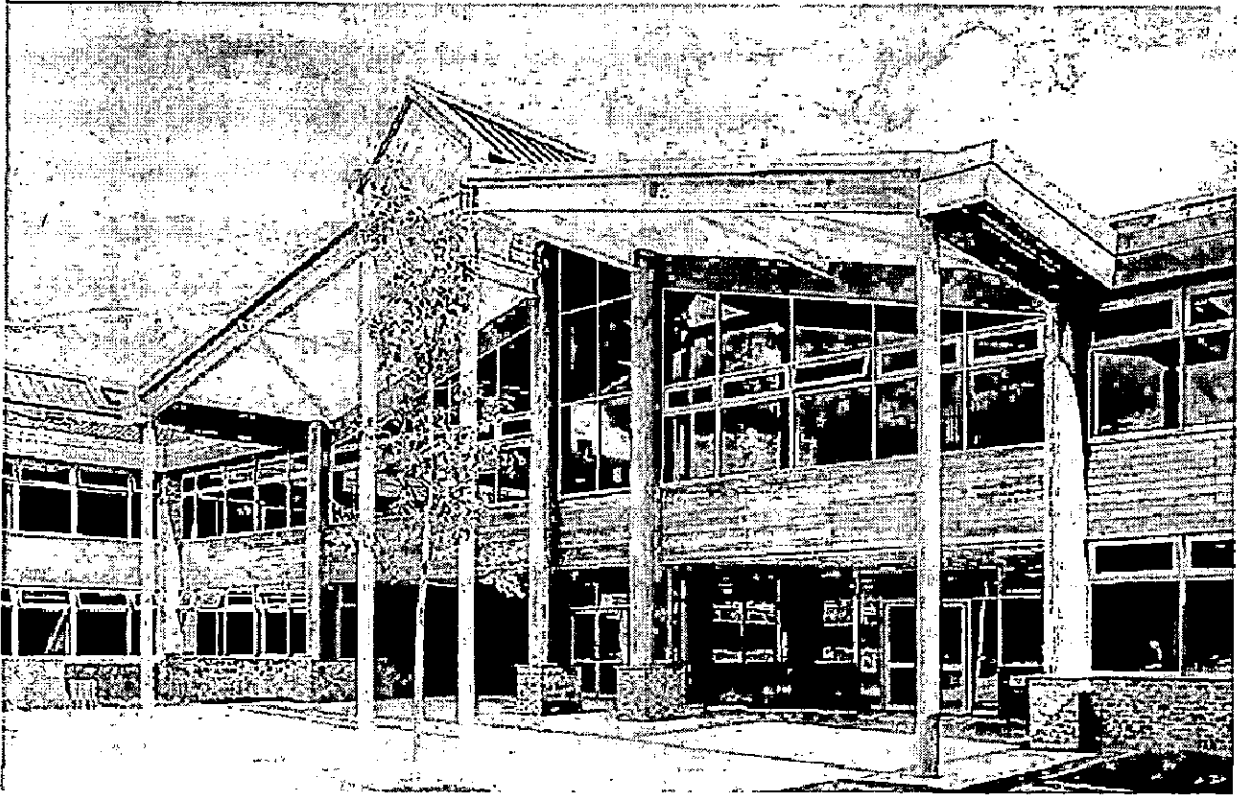
**TABLE 2.2. CORRECTION FACTORS FOR LUX METERS**

Poor lighting in the workspace can be due to variety of reasons --

1. Inefficient lamps and/or ballasts
2. Mounting height of lamps too high
3. Reflectors of poor luminaire efficiency
4. Maintenance of reflectors not proper due to dirt/dust accumulation
5. Poor Maintenance of wall, floor and roof reflectance levels
6. Reduction in light output of lamps over time due to lumen depreciation

### 3 CHAPTER 3 - LIBRARY CASE STUDIES

#### 3.1 WORLD'S END SCHOOL, ENFIELD



#### 3.1. WORLD'S END SCHOOL

**Architect - Architects' Co-Partnership (ACP)**

**Client - London Borough of Enfield**

Classroom designs had to meet the requirements of the London Borough of Enfield, where the illumination levels required were given as 300-500 lux, depending upon the activity within.

E-shaped configuration of classrooms with daylight entering from windows either side, with a linear pitched roof light down the centre to balance the daylight.

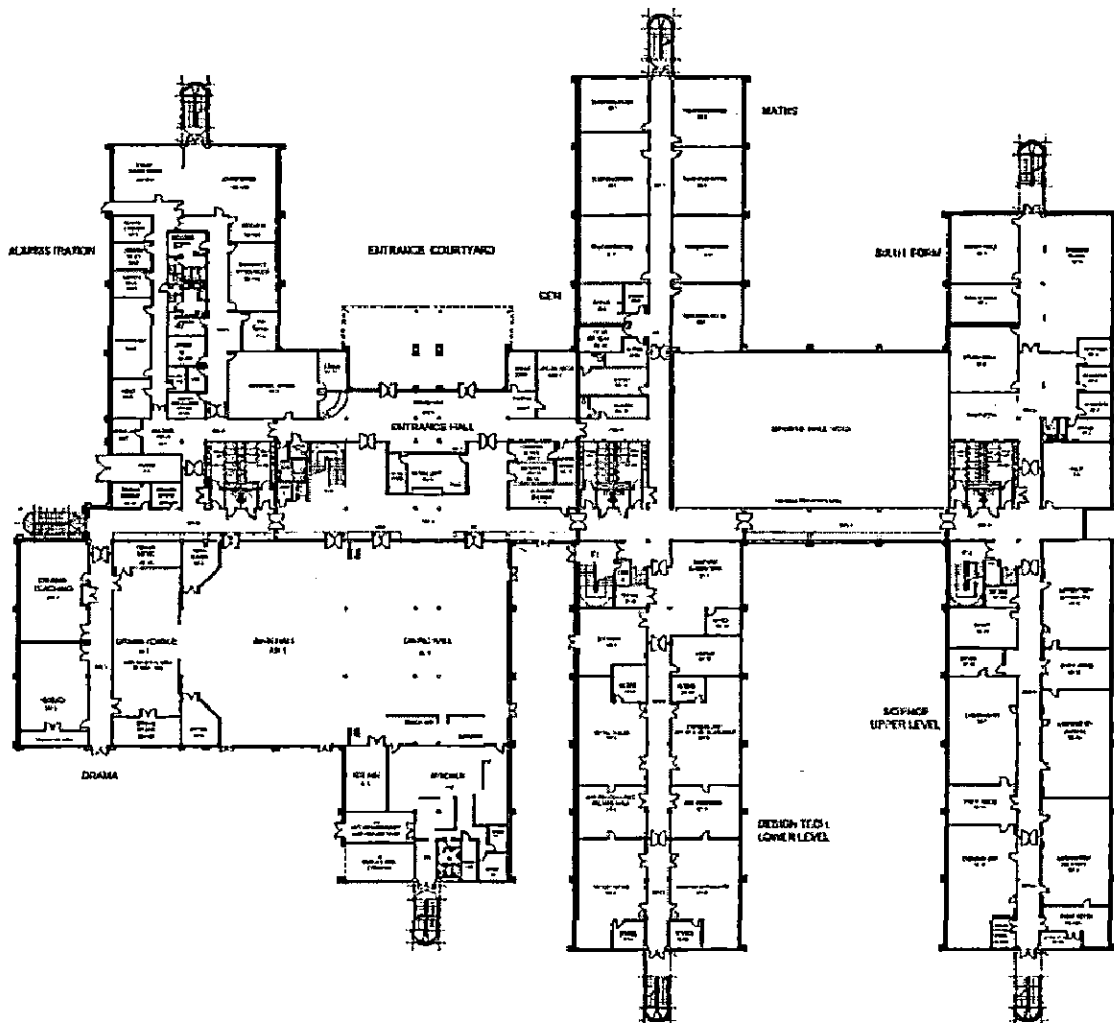
Daylighting requirement suggested that the depth of all classrooms should not exceed 7m. The room heights were standardized at 2.985m, with a sill height of 0.95m in order to ensure that the amount of available daylight would reach the minimum standards set. This led to a window area of 65 per cent of the external wall.

Windows are double glazed, with the external pane comprising low emissivity 'grey' tinted glass, to reduce solar gain. Windows to the south, west and east have all been fitted

with internal blinds between the double glazed panes, to provide individual control when required. Ventilation is achieved by top hung opening lights.

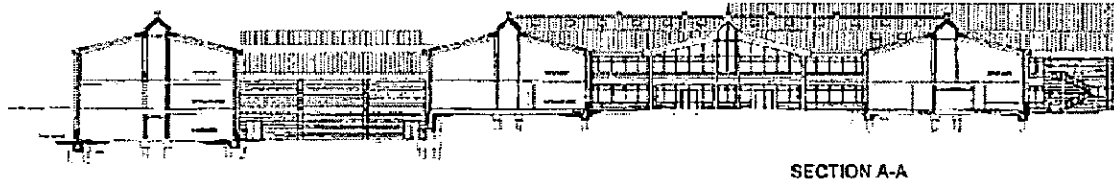
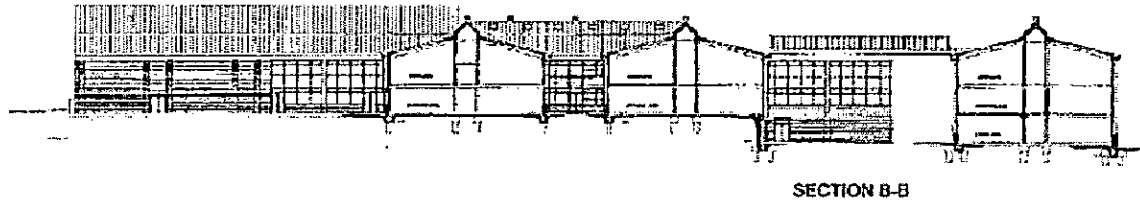
Engineers provided a daylight analysis for the sports hall, which indicated an average daylight factor of 3.8 per cent from a small area of overhead daylighting, which whilst lower than Ministry guidelines, was thought to provide 300 lux over the floor area for 75 per cent of daylight hours.

The control of the artificial lighting is by manual switching in the individual areas; since there is no BEMS there is no opportunity for daylight linking, and it is left very much up to the person in charge of the classroom to make decisions as to whether the artificial lighting is required to supplement the daylighting at any particular time.



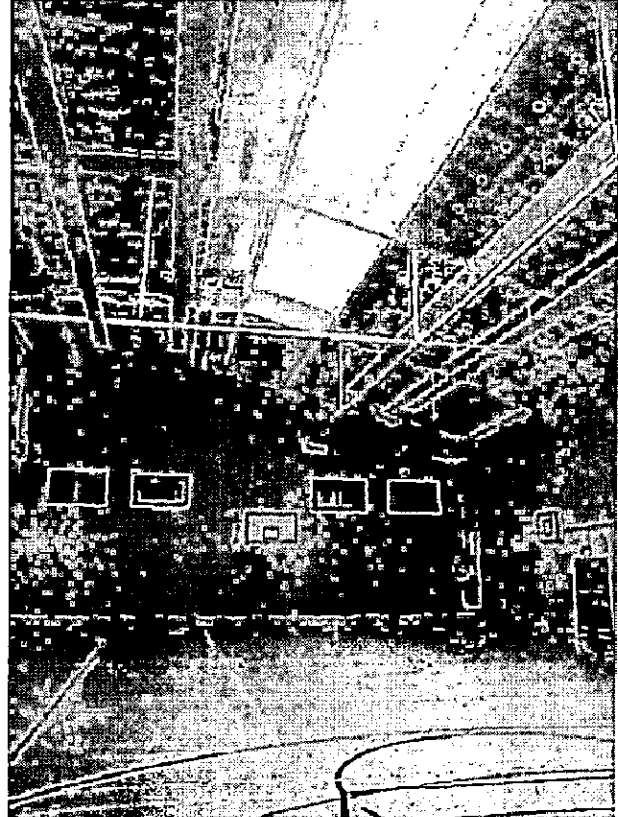
Plan at ground level

### 3.2. GROUND FLOOR PLAN



Section to show classroom wings and rooflight

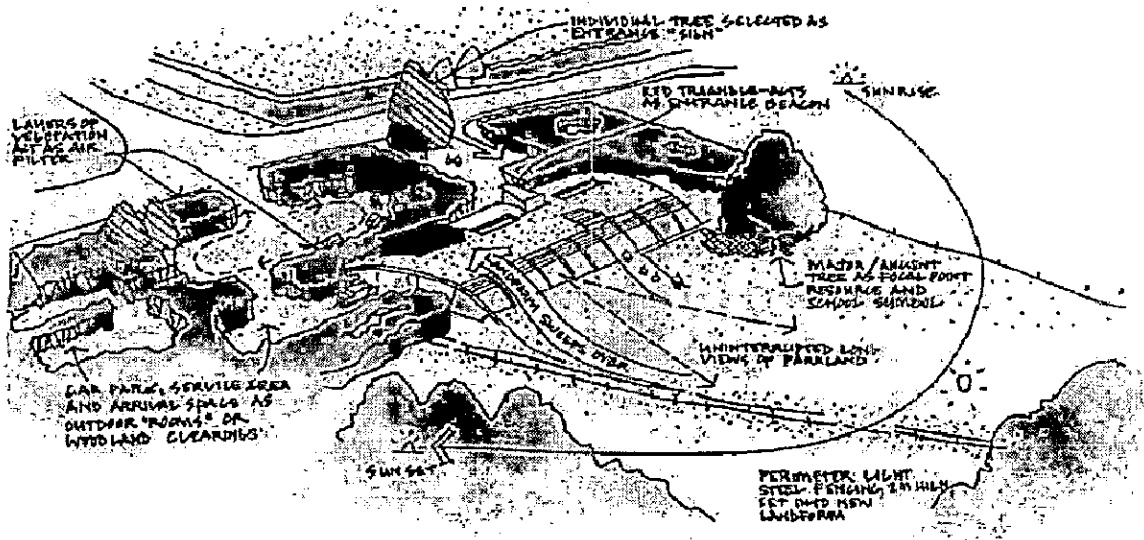
### 3.3. SECTIONS



### 3.4. CIRCULATION SPACE AND SPORTS HALL



### 3.2 RIVERHEAD SCHOOL, SEVENOAKS



### 3.5. CONCEPT

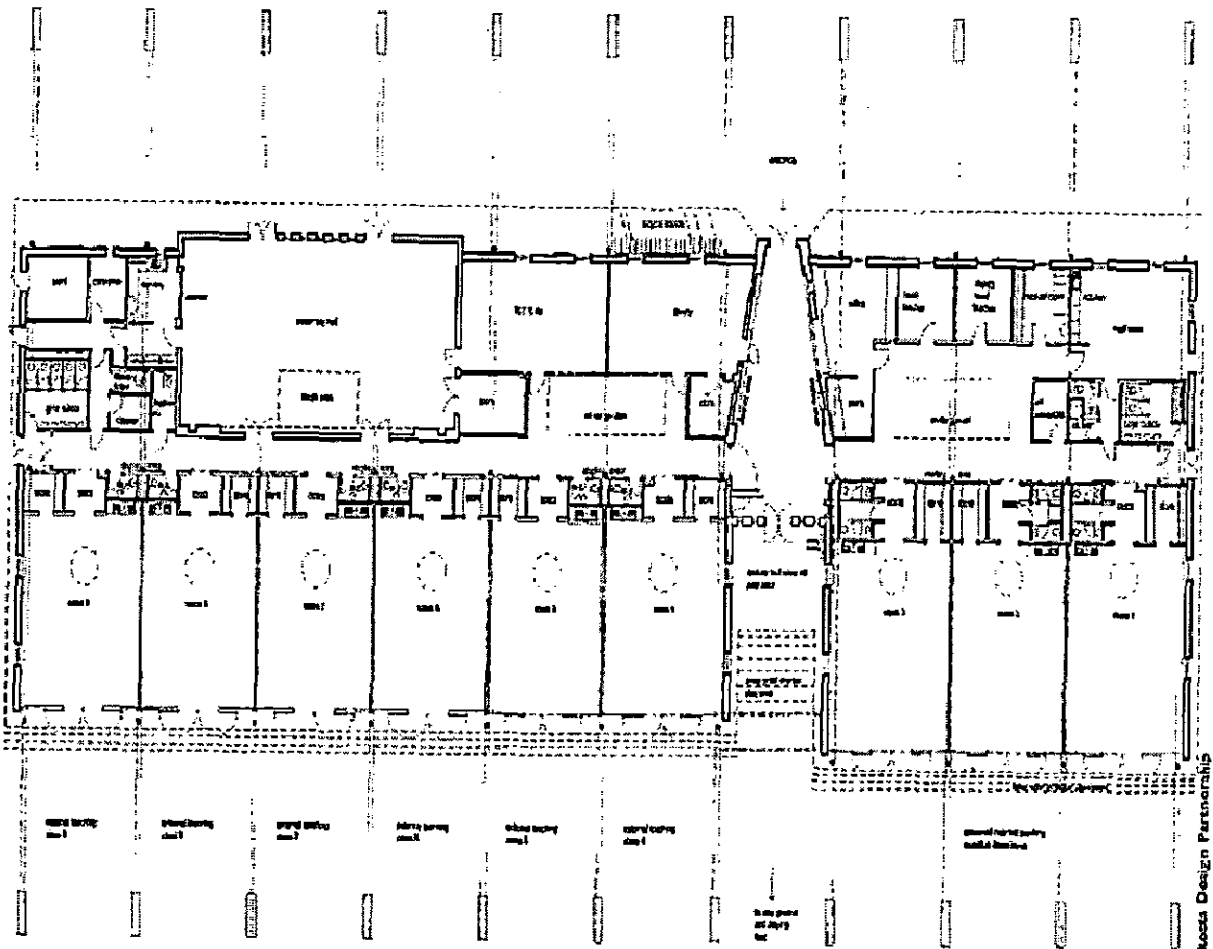
**Architect - Architects Design Partnership**

**Client - Kent County Council**

It was designed to be a 'green building' to fit into the landscape, and to be both educationally and environmentally responsive. The school is designed to house 270 pupils, and is not thought to require future expansion. The form of the building consists of an arch section facing south housing all the teaching areas. The roof fits into the landscape by being covered in vegetation.

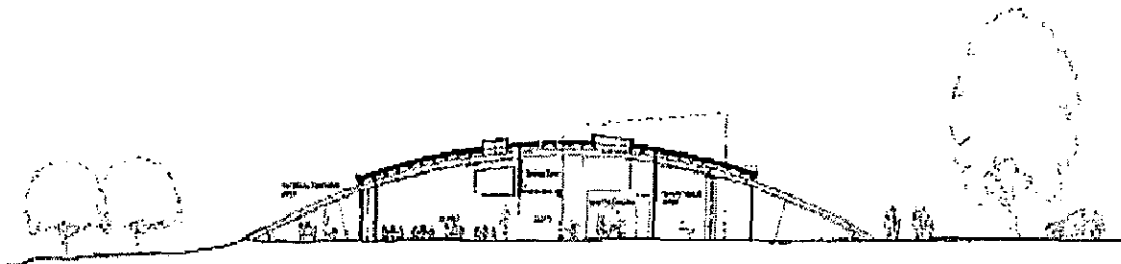
Teaching classrooms open to the south on to landscaped areas, and are all daylit by means of the window walls, associated with circular roof lights to the rear of the spaces. The classrooms open out on to external teaching spaces, and these are divided up by removable canvas 'sails' which are stretched across between the classrooms; these provide both privacy and protection,

Air freshness is a particular concern in classrooms, and when it is too cool or windy to open up the glazed double doors; vents are available above the door heads, together with the openable roof light to provide air movement. The curved section of the building assists in which the ceiling rises towards the roof light, similar to the useful ventilation volume provided by the traditional high ceiling of the Victorian schoolroom.



Architects Design Partnership

Building plan

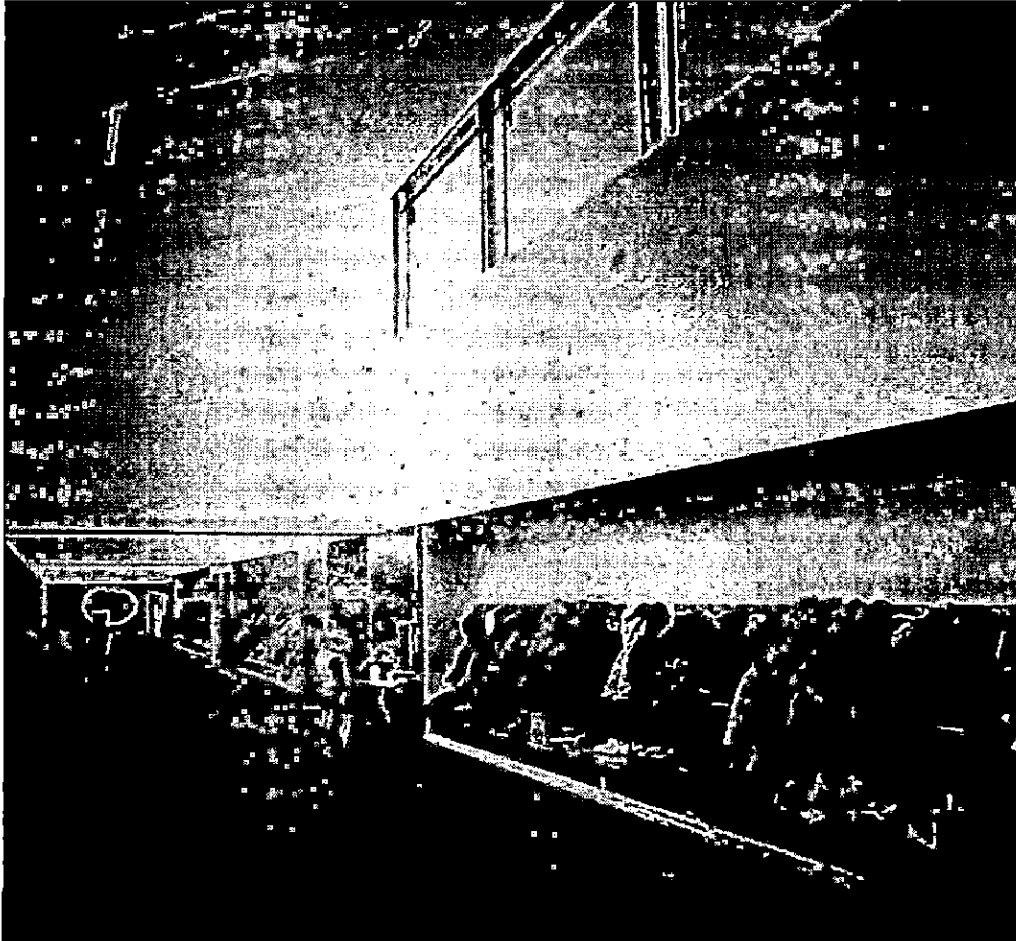


Architects Design Partnership

Building sections

### 3.6. BUILDING PLAN AND SECTIONS

### 3.3 SUTTON ELEMENTARY SCHOOL, MASSACHUSETTS



#### 3.7 SUTTON ELEMENTARY SCHOOL

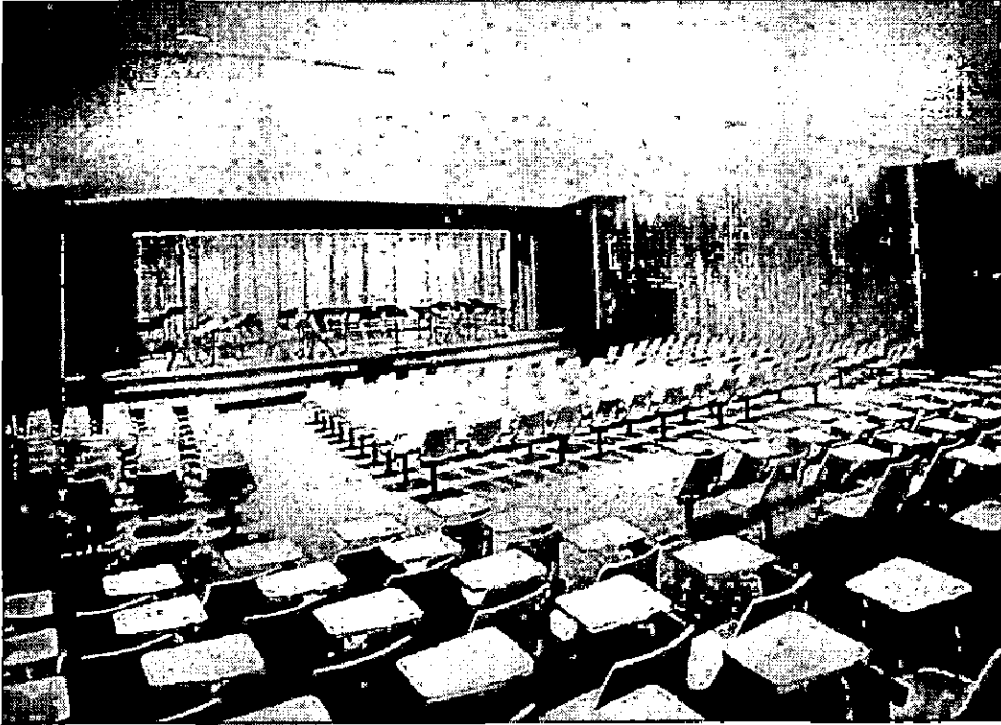
**Architect – Johnson- Hotvedt and Associates**

**Client – Sutton School**

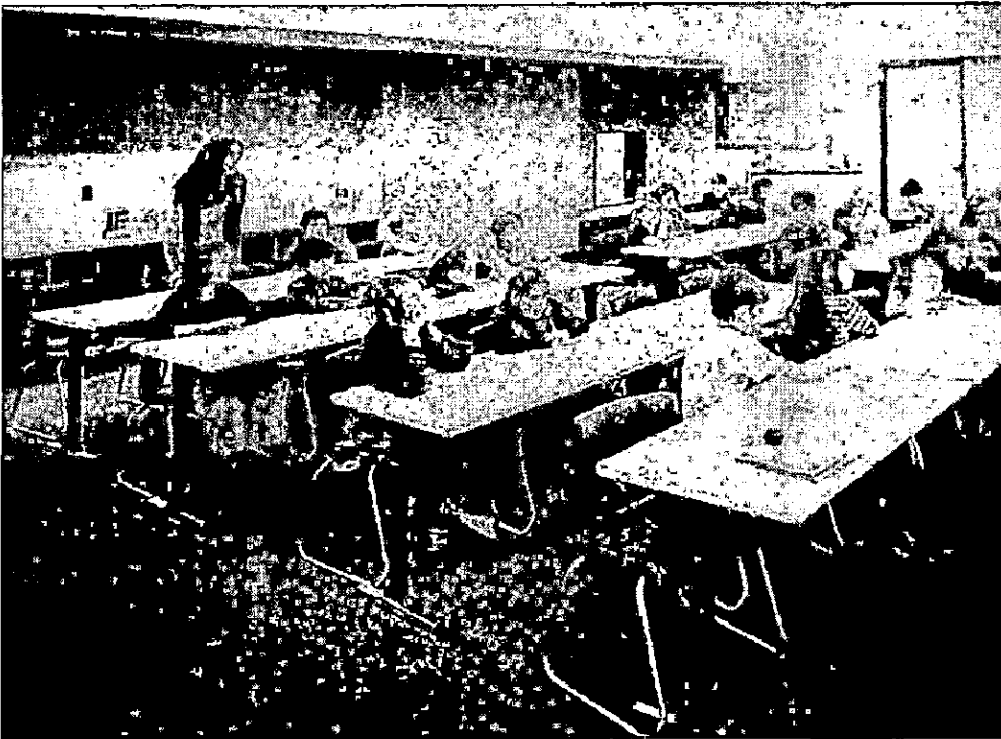
This building takes its distinctive character from the deep plaster enclosed steel structure that spans between the main corridor and perimeter walls, creating 20-foot-wide bays. This frame offered a means for providing consistent indirect lighting approach.

Continuous extruded aluminum cove fixtures were mounted on the bottom edges of the main beams that define the bays. Several lines of monitored clerestory windows were introduced due to long spans. These define the main corridor and edges of the classrooms. Corridor monitors admit sunlight that helps to meet biological information needs for sunlight, weather and time orientation.

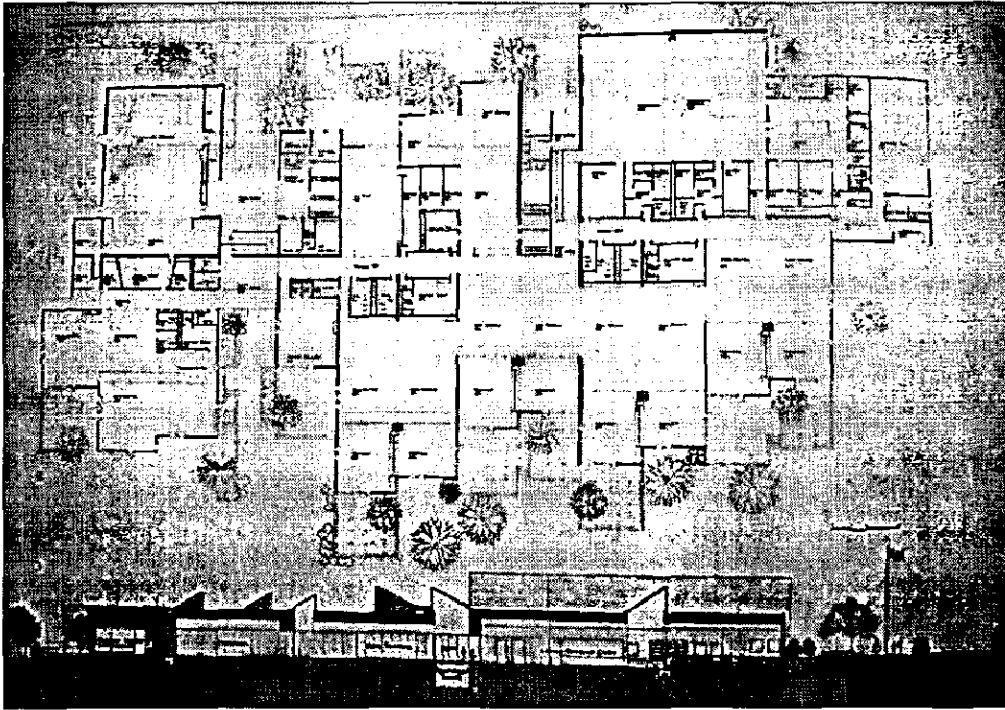
The walls of the windowless auditorium are lit from slots at the top that has the effect of floating the suspended ceiling free from the walls. This slot system is supplemented by recessed downlights in the ceiling that are dimmable and can be used for note-taking.



3.8. AUDITORIUM



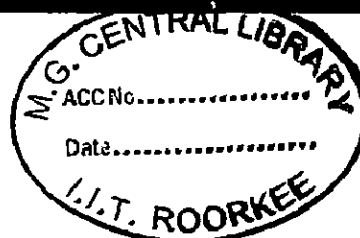
3.9. CLASSROOM

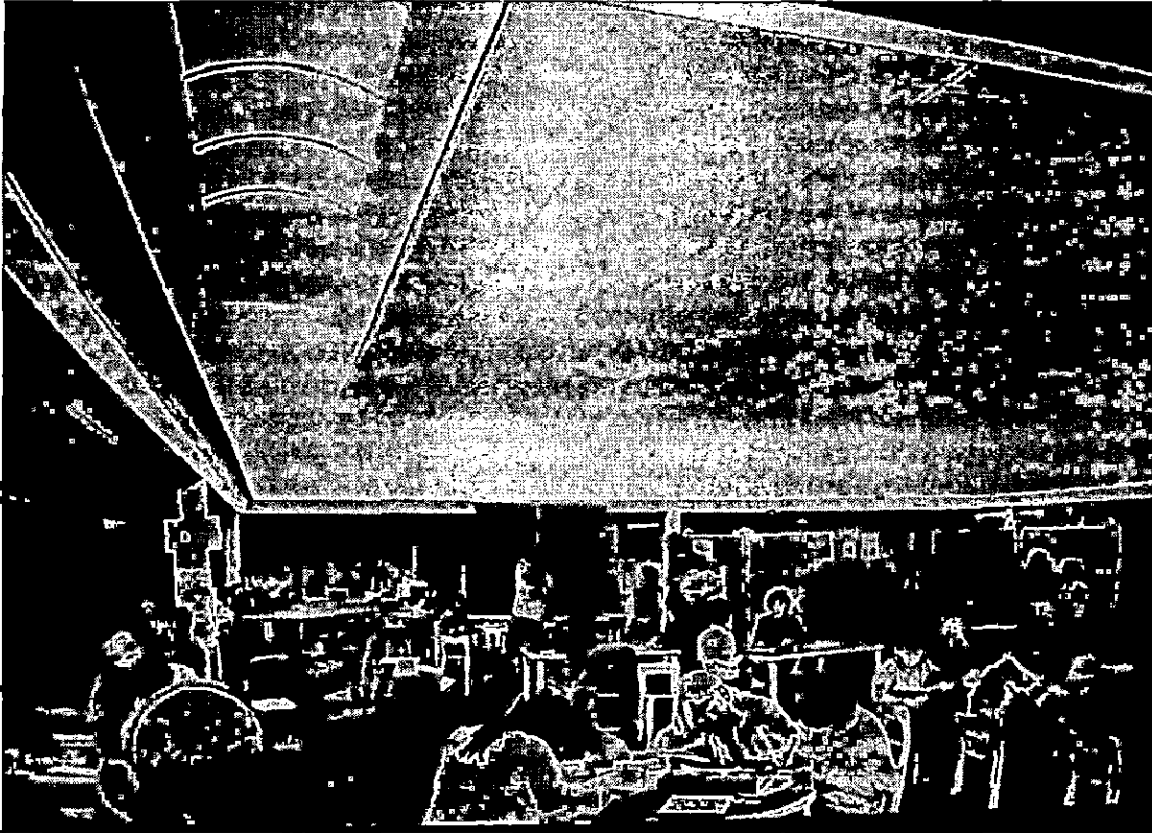


3.10. PLAN AND SECTION



3.11. LIBRARY



**3.4 ELEMENTARY SCHOOL AND AREA HIGH SCHOOL, NEW HAMPSHIRE****3.12. CENTRAL ROOM**

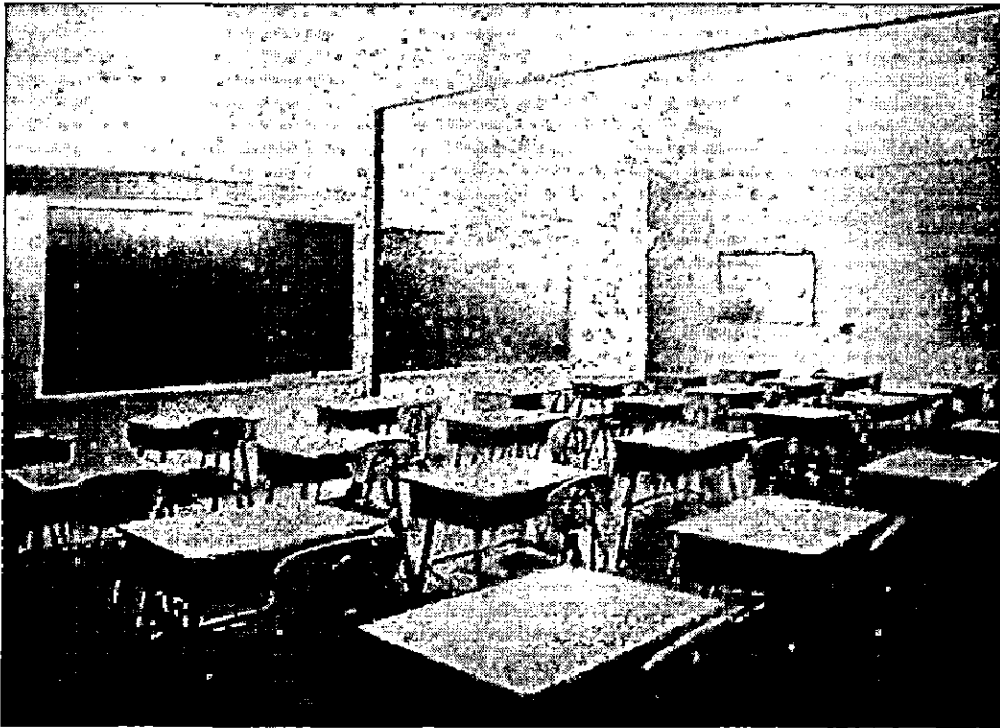
**Architect – Johnson- Hotvedt and Associates**

**Client – Plymouth School**

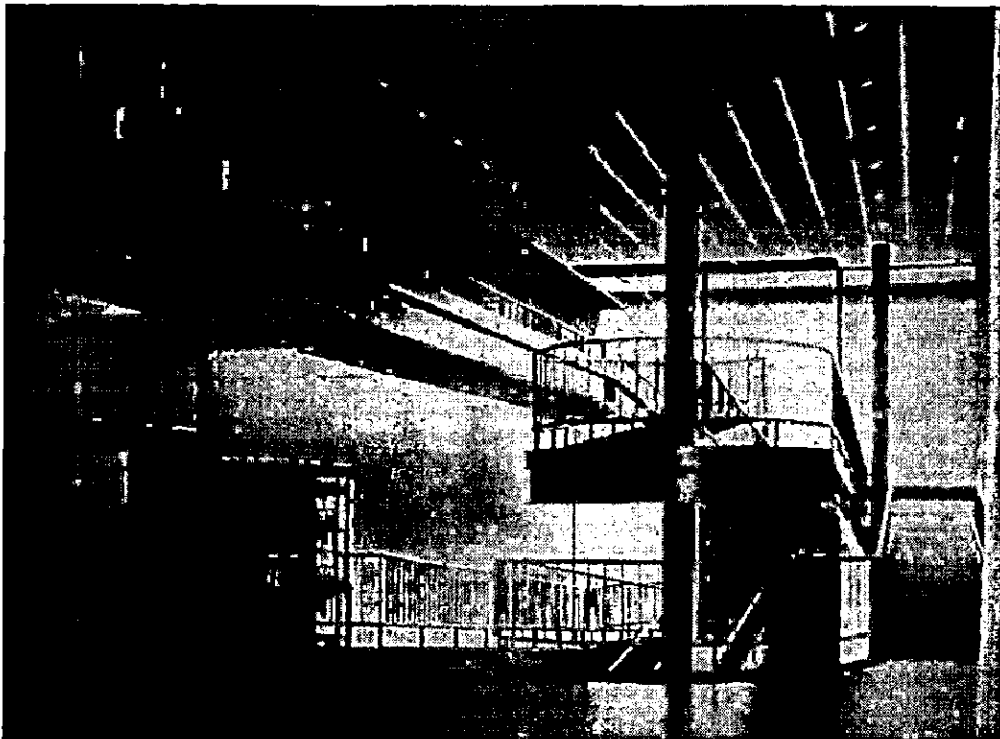
All spaces are massed along fixed corridors in major clusters joined by lobbies, in a linear scheme. Corridor ceilings were lowered to provide channels to accommodate all major services. This made it possible to integrate lighting design into the fixed corridors. Major lighting comes from these elements. Lighting was kept away from transverse walls as they vary in their spacing. Indirect lighting was supplemented by track mounted incandescent fixtures.

Exterior and corridor walls of the central room were defined by skylights. Shape and position of ducts were decided by lighting. Where low ceiling heights and seating made indirect lighting difficult, low brightness fluorescent downlights were used.

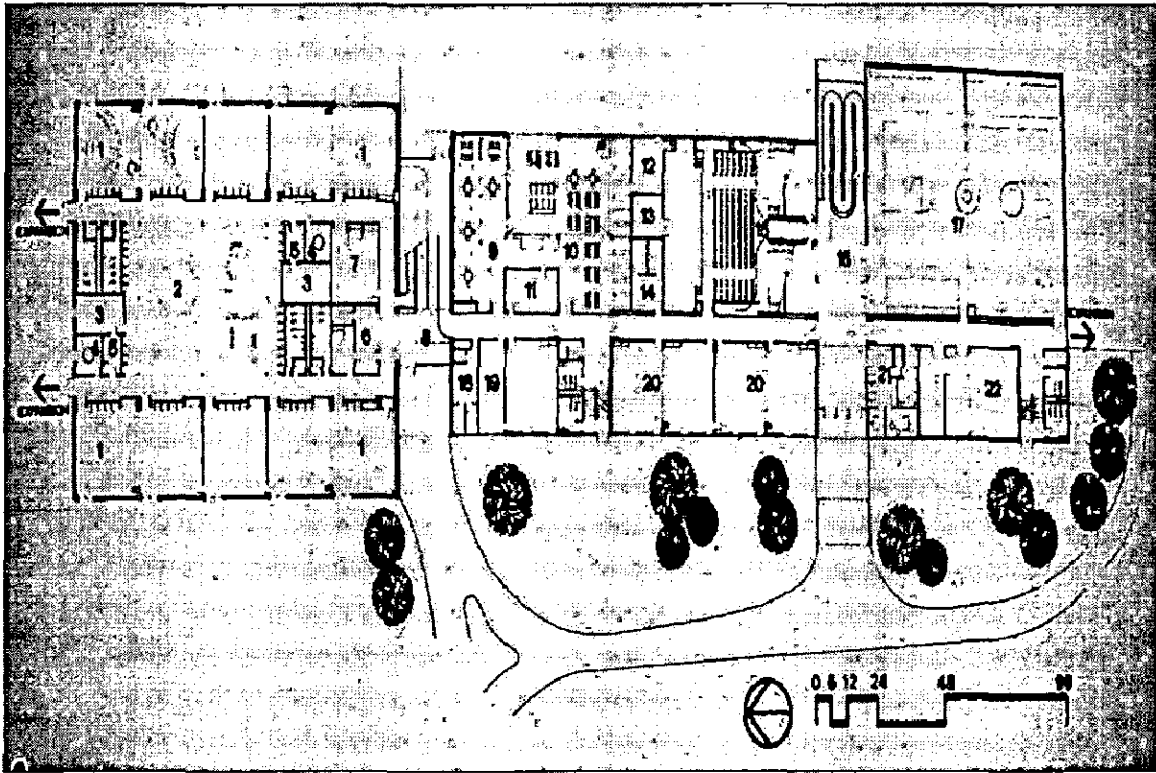
Connecting lobbies were treated as weather enclosures for intervening spaces that are crossed by bridges and ramps. Walls spanning between the major masses are fully glazed. Daylight is supplemented by illumination from end walls of the masses from fixtures on tracks.



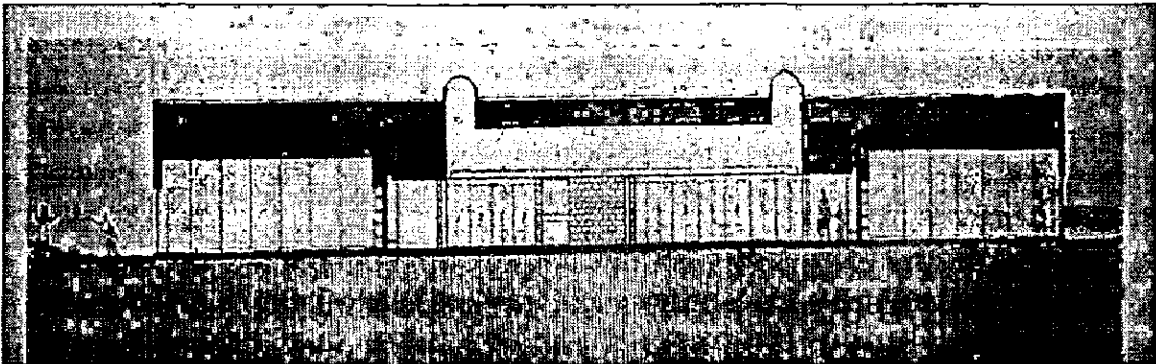
**3.13. INDIRECT LIGHTING**



**3.14. CONNECTING LOBBY**



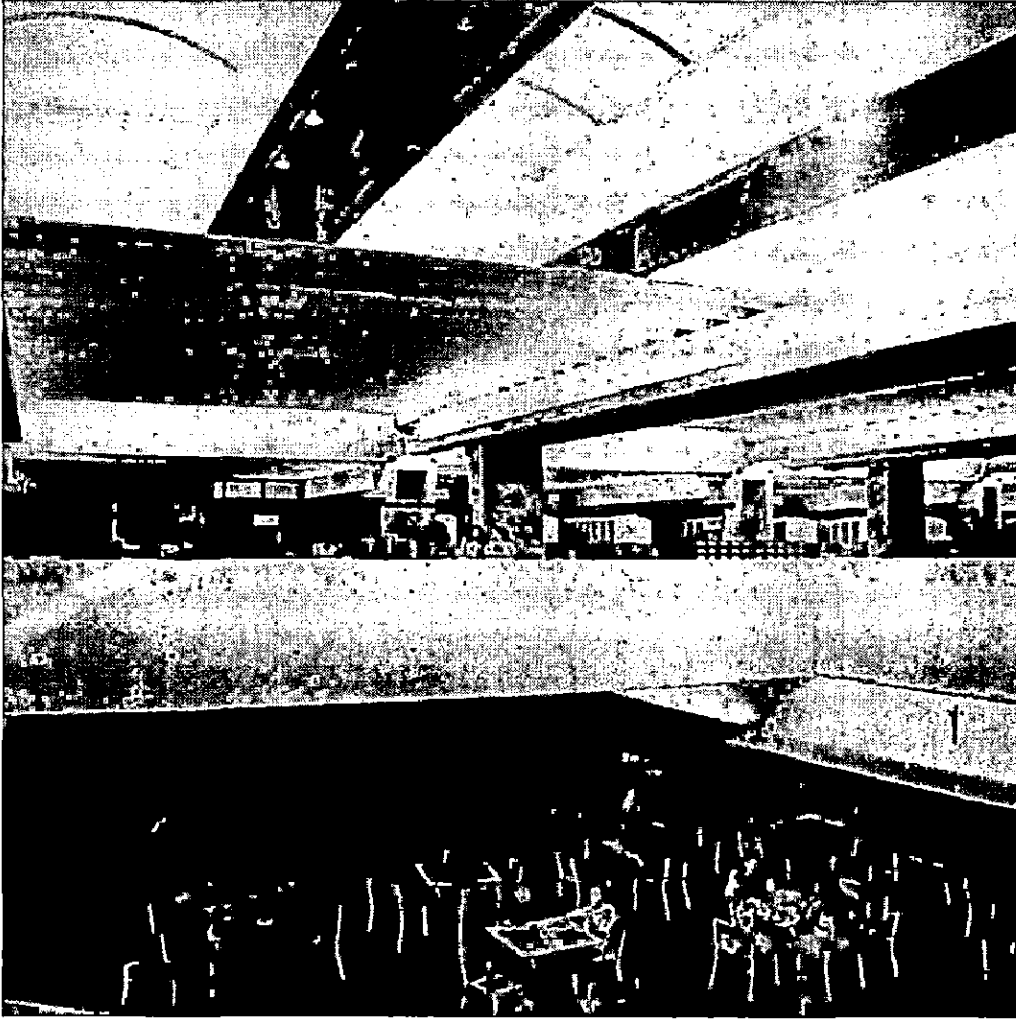
3.1. PLAN



3.2. SECTION



### 3.5 PIERREFONDS COMPREHENSIVE HIGH SCHOOL, QUEBEC



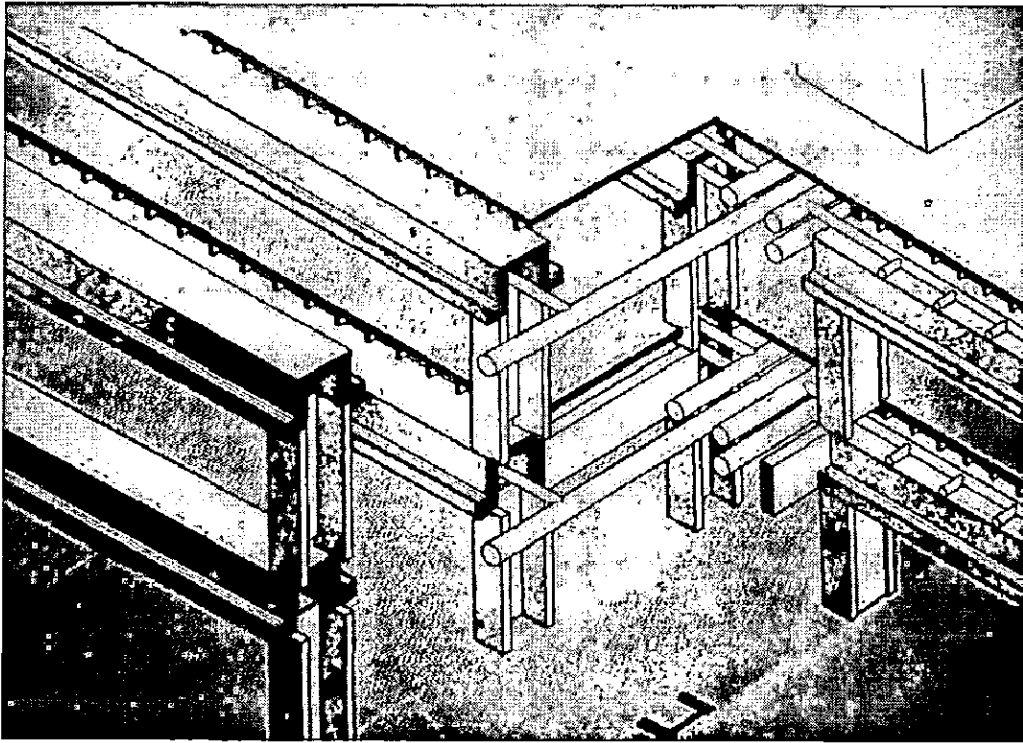
#### 3.3. PIERREFONDS COMPREHENSIVE HIGH SCHOOL

**Architect – Affleck Desbarats Dimakopolous Lebensold & Sise**

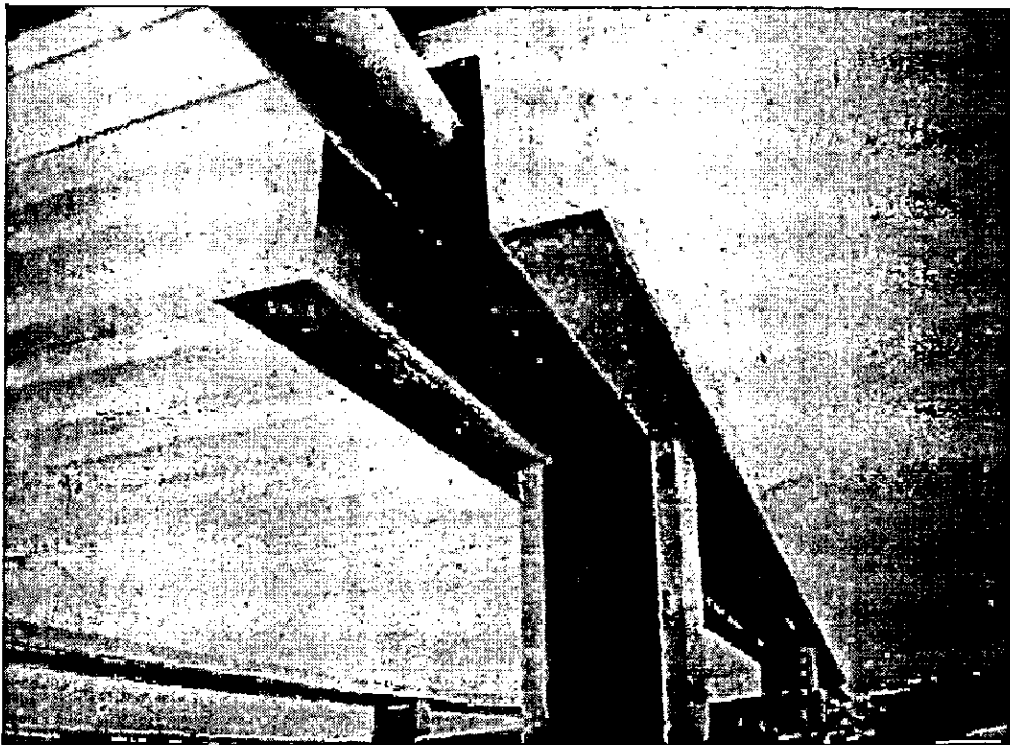
**Client – Pierrefonds School**

The design concept was to build an articulated, flexible design. Detailed planning came after developing the concept for systems-of-systems that would integrate services, structure and lighting. Structure was designed to create long bands of indirectly lit concrete coffers alternating with service channels to enclose ductwork and plumbing. System was designed around precast concrete channels that contain mechanical services, span up to 70 feet and double as lighting coves.

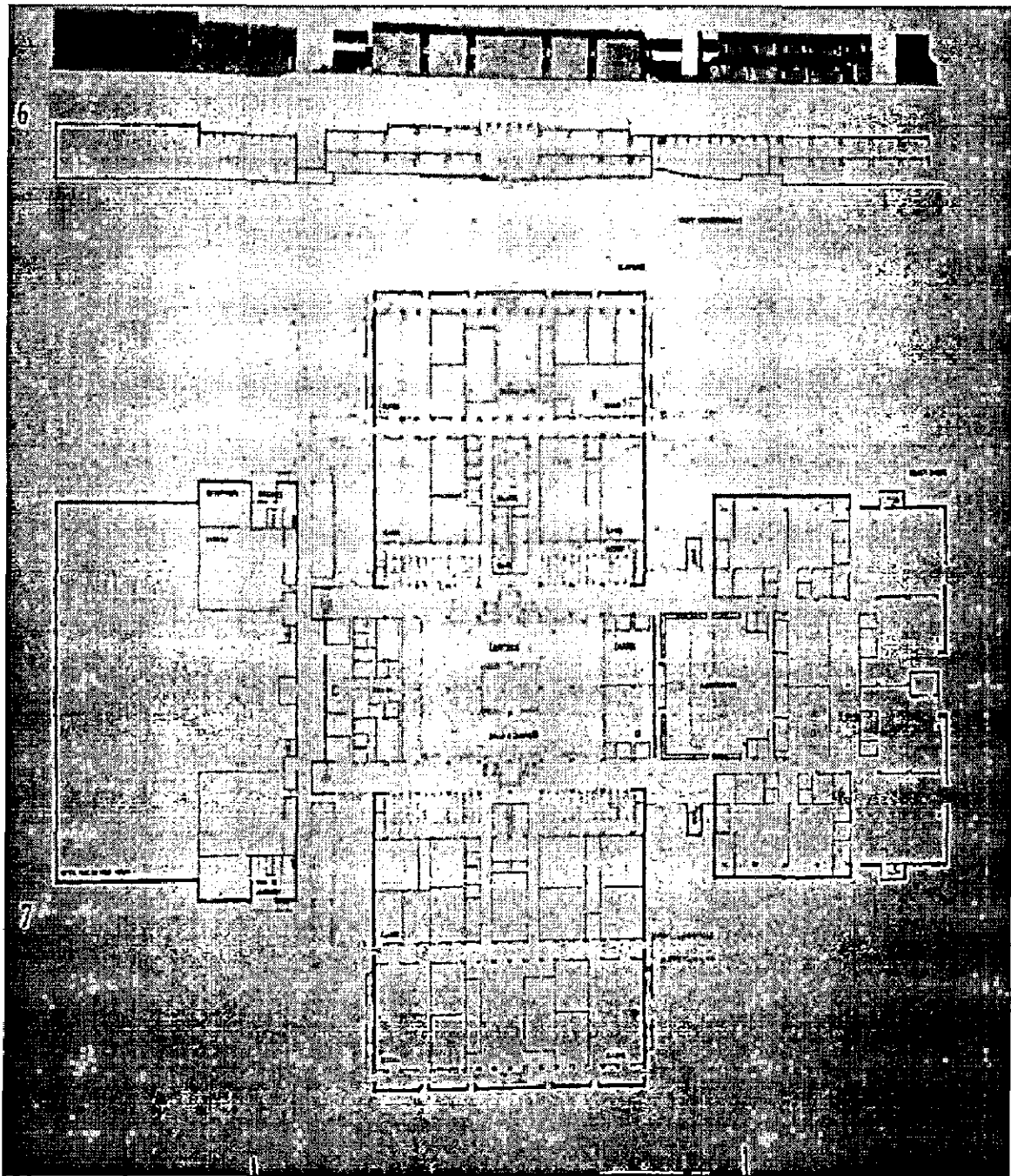
Cross partitions and corridors perpendicular to channel beams can be placed anywhere without interrupting the lighting system. Fluorescent strip fixtures are distributed to accommodate partitions. Indirectly lit ceiling coffers cast enough light on vertical surfaces. Mounting bare lamps behind beams on open channels is sufficient to light walls too.



**3.18. AXONOMETRIC STUDY OF SYSTEMS**



**3.19. PRECAST CONCRETE CHANNELS**



3.20. PLAN AND SECTION

**3.6 ANALYSIS**

Analysis of various case studies has been done by co-relating three main factors.

**Spaces**

Various areas in a school building that are considered for lighting purpose. These may be fully enclosed, partially enclosed or open areas.

**Lighting parameters**

Sources of light in a space can be either natural light or artificial light. Amount of light in a space may be insufficient, sufficient or excessive.

**Design parameters**

These consist of factors that affect amount and quality of light entering a building. These include site location, building orientation, building form, façade treatment, indoor surface quality, etc.

These three can be interrelated by forming a matrix.

	LIGHT QUALITY		
	UNCOMFORTABLE	SUFFICIENT	INSUFFICIENT
TYPE OF WINDOW			
WINDOW AREA			
TYPE OF GLAZING			
WINDOW POSITION			
WINDOW ORIENTATION			
SIZE OF SPACE			
LAYOUT			
INDOOR SURFACE			

**TABLE 3.1 COMPARISION CHART**

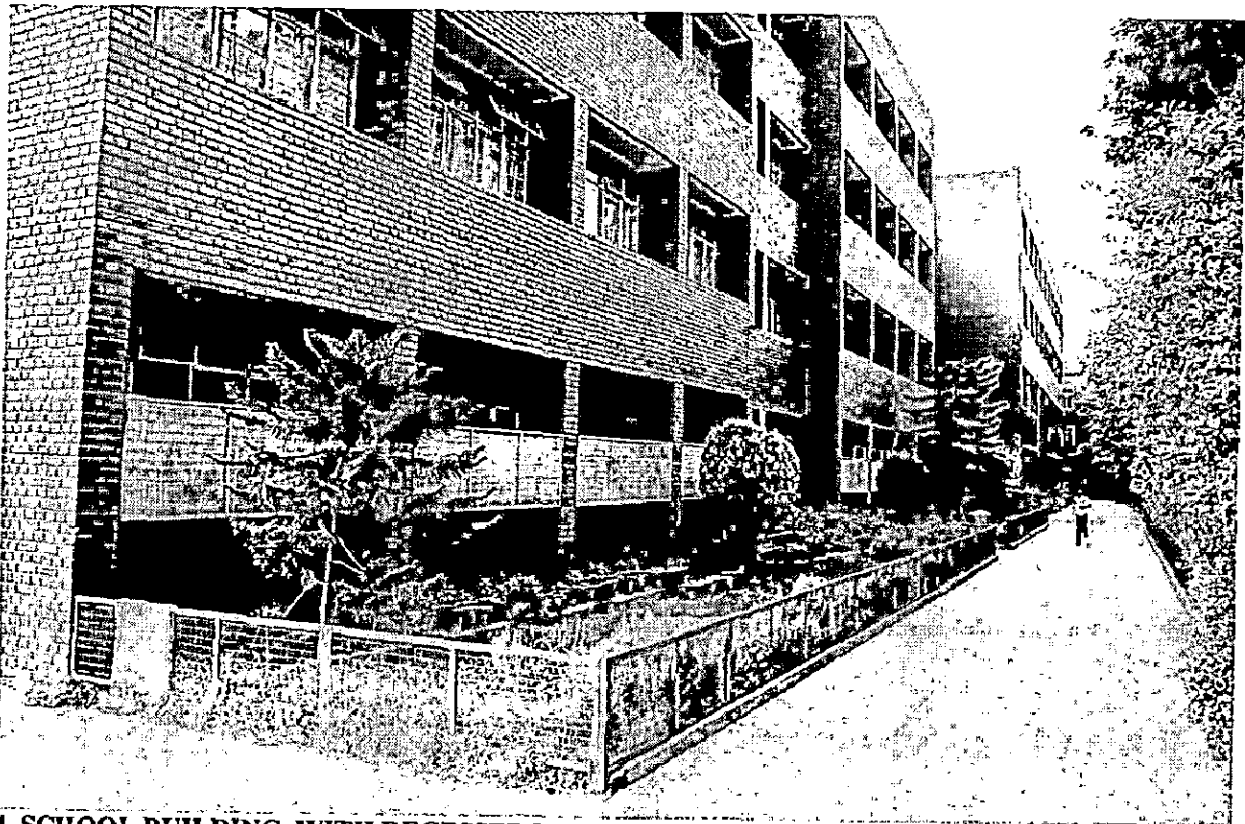
This type of chart can be used to find a pattern between various recurring design parameters for a space and how they affect the quality of light entering the space being considered. This in turn, will help one to determine exactly the various design parameters that can be used to determine most efficient techniques to be considered according to different conditions.

Literature provided information about various essential lighting and design parameters that go into doing lighting design for any space. It explained importance of several terminologies involved. It also gave information about various methods of control of lighting, whether artificial or natural.

#### **4 CHAPTER 4 - RESULTS AND DISCUSSIONS**

Lighting in a space is dependent on several parameters such as plan form, floor area, room volume, window to floor area ratio, type of sunshading, etc. Observations were made in 14 classrooms and 7 laboratories in 4 different schools, all falling in composite climate zone. These parameters were measured and recorded.

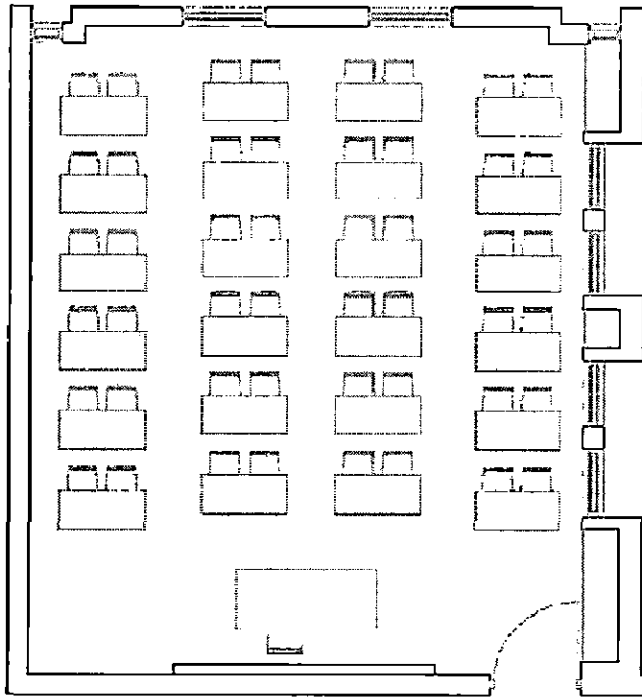
The illuminance levels for the spaces were compared to the recommended levels specified by the National Building Code (2005). It was seen on some of the examples that illuminance levels were sometimes within the recommended levels specified by the NBC, or they were over the prescribed limits. Sometimes, in the same school, lot of difference was observed in the average illumination levels.



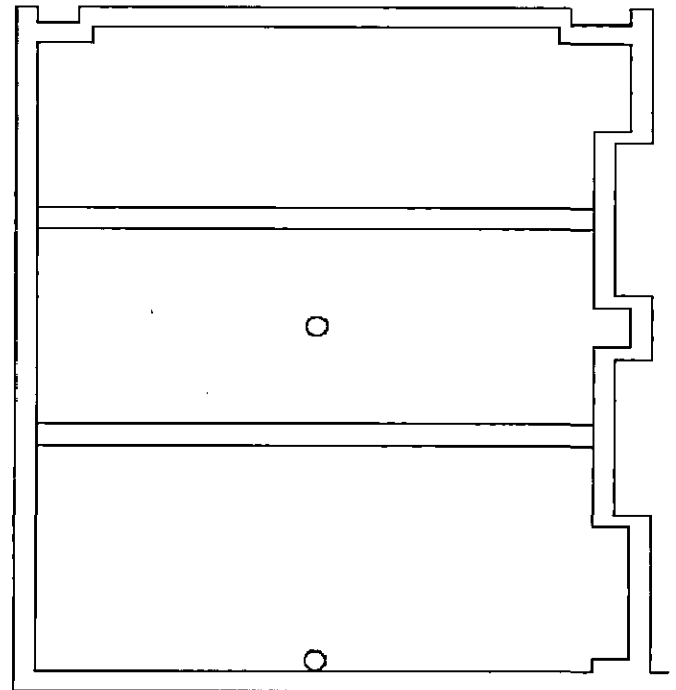
**4. SCHOOL BUILDING, WITH RECESSED WINDOWS**

The schools that were chosen for the study are all in the composite climate zone. The areas that were studied were classrooms and laboratories.

**4.1 OBSERVATIONS FOR SCHOOL 1 – ADARSH BAL NIKETAN SENIOR  
SECONDARY SCHOOL  
TYPE 1 CLASSROOM**



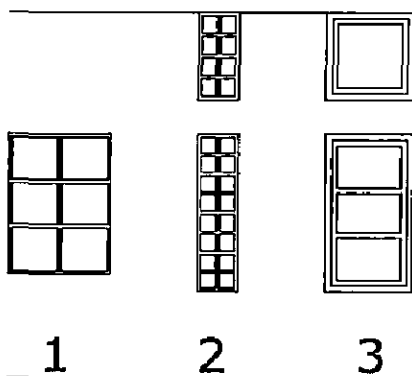
4.1.1. TYPE 1 CLASSROOM PLAN



4.1.2. CEILING PLAN SHOWING FIXTURES

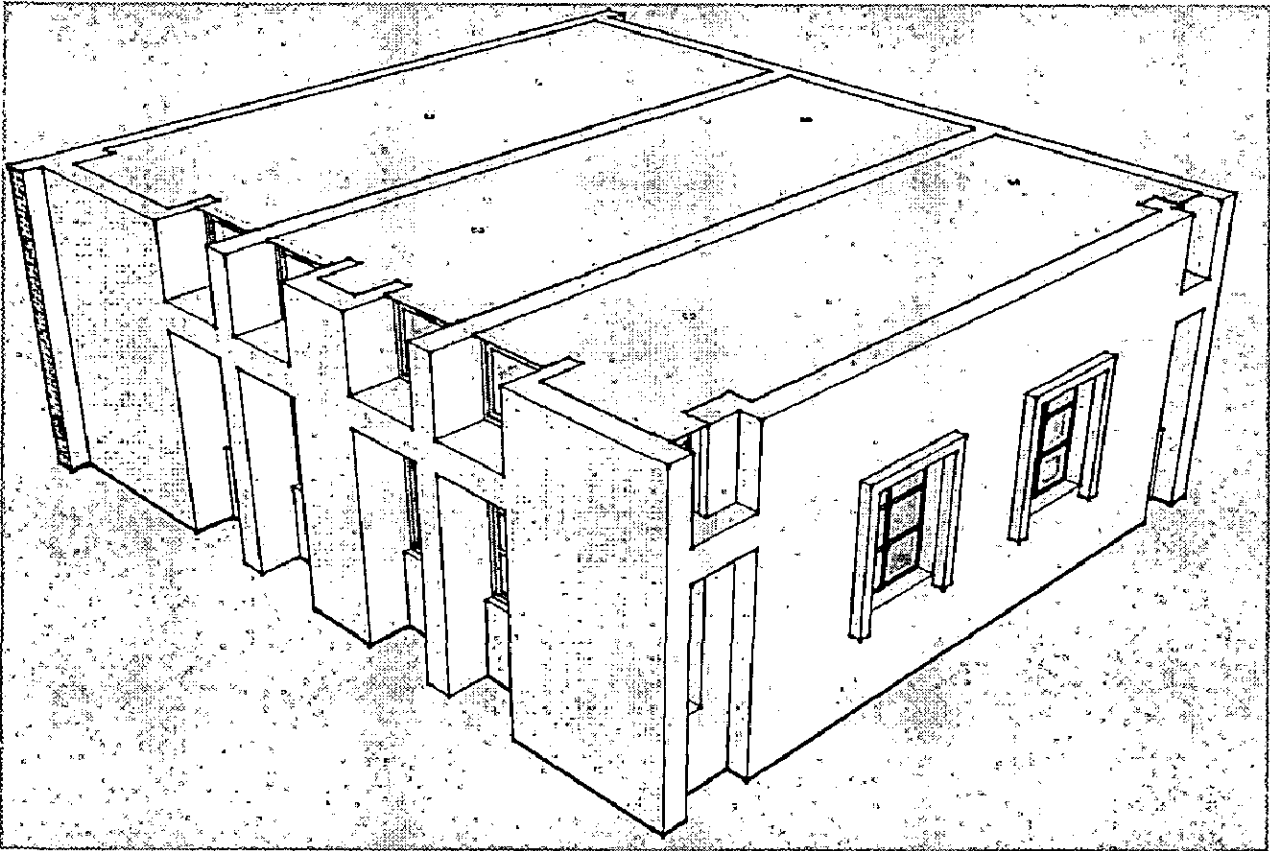
The floor area for Type 1 classroom is 44.2 sq.mts. Windows are provided on the North West and South West facing walls. Three different types of windows have been provided.

Window type 1 has 90cms sill height, 210cms lintel height and 90cms width. Window



type 2 has 75cms sill height, 210cms lintel height and 35cms width. Window type 3 has 75cms sill height, 210cms lintel height and 75cms width. Windows types 2 and 3 have ventilators above them that have 240cms sill height and 315cms lintel height. Total window area is 9.93 sq.mts, so window to floor area ratio is 22.46%.

4.1.3. TYPES OF WINDOWS USED



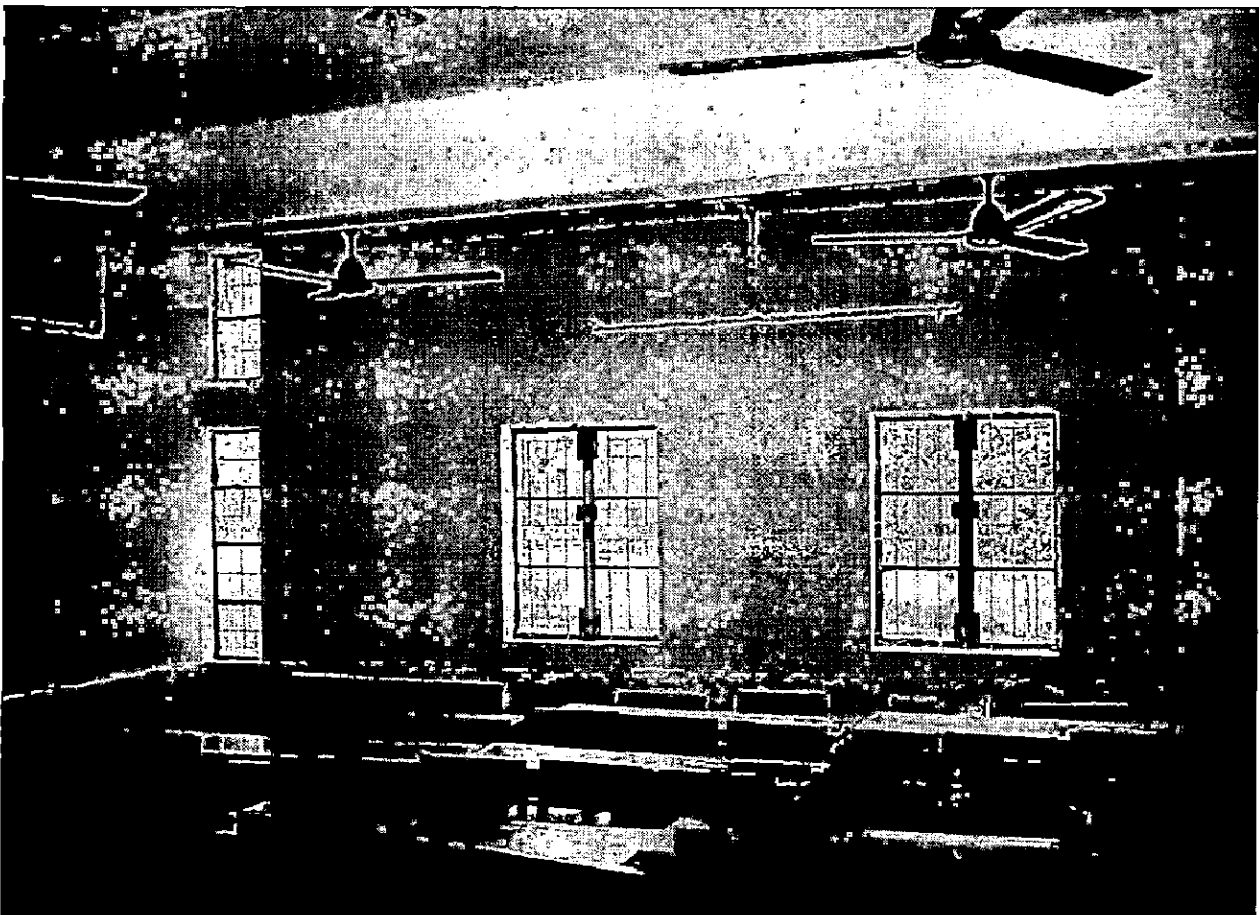
**4.1.4. EXTERIOR WALL FACADE ON WINDOW SIDES**

Windows on the North West wall are recessed. Only Type 2 windows on South West walls are recessed, type 1 windows have no sunshading. The class orientation is from South West to North East. Light enters the room from the left and rear of the classroom. Inner walls have been painted matte yellow up to sill height and white above it. No window blinds or curtains have been provided. Ceilings have been painted white and floor has a polished cement finish. Only two luminaires have been provided. Both are 100 Watt incandescent fixtures.

It is observed that the illuminance levels in this classroom are maximum near the windows and minimum at the farthest corner from the windows. The average illuminance is within the accepted range. Artificial lighting does not make a significant difference in the level of illuminance but it is not really necessary under normal sky conditions and normal operating hours of the school. Towards the corners of the room, light is slightly blocked by the user when he/she sits at the desk but it is not significant enough to impair tasks.

LIGHT LEVELS IN ROOMS (IN LUX)	DAYLIGHT	ARTIFICIAL LIGHT
BLACKBOARD	185	200
WINDOW CORNER	450, 590	485, 630
MIDDLE OF ROOM	220, 620	245, 665
FARTHEST CORNER	145, 360	165, 380
AVERAGE	348.78	375.92

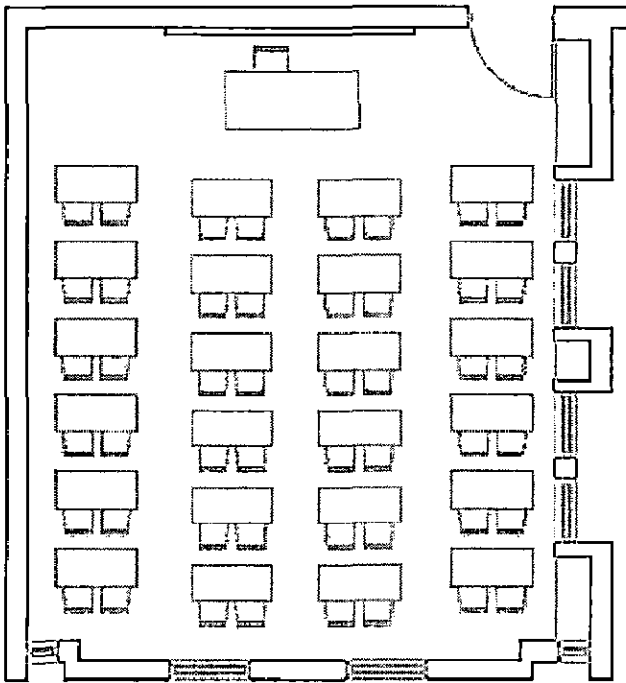
TABLE 4.1.1. ILLUMINANCE LEVELS FOR TYPE 1 CLASSROOM



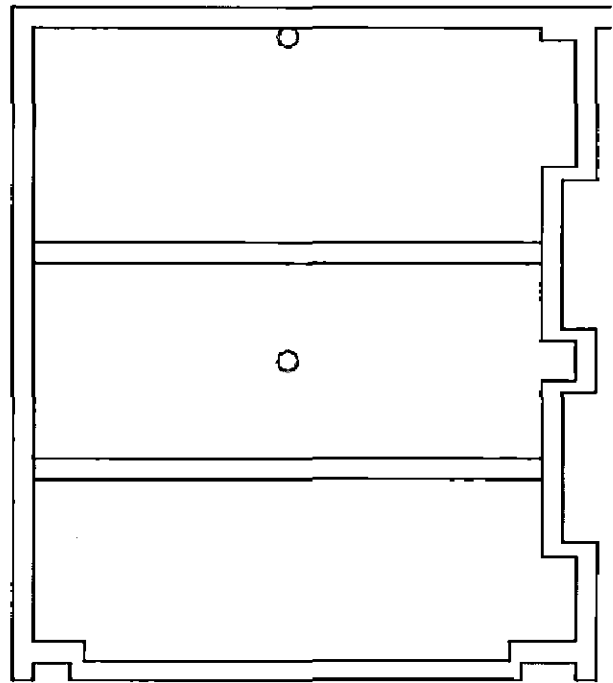
4.1.5 CLASSROOM IMAGE



**TYPE 2 CLASSROOM**



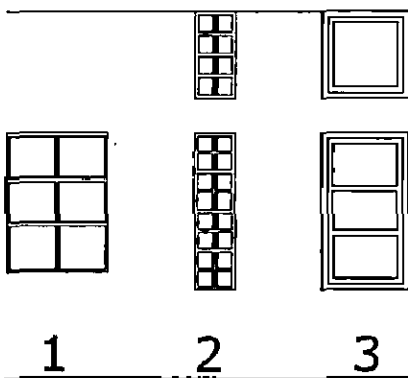
**4.1.6 TYPE 2 CLASSROOM PLAN**



**4.1.7. CEILING PLAN SHOWING FIXTURES**

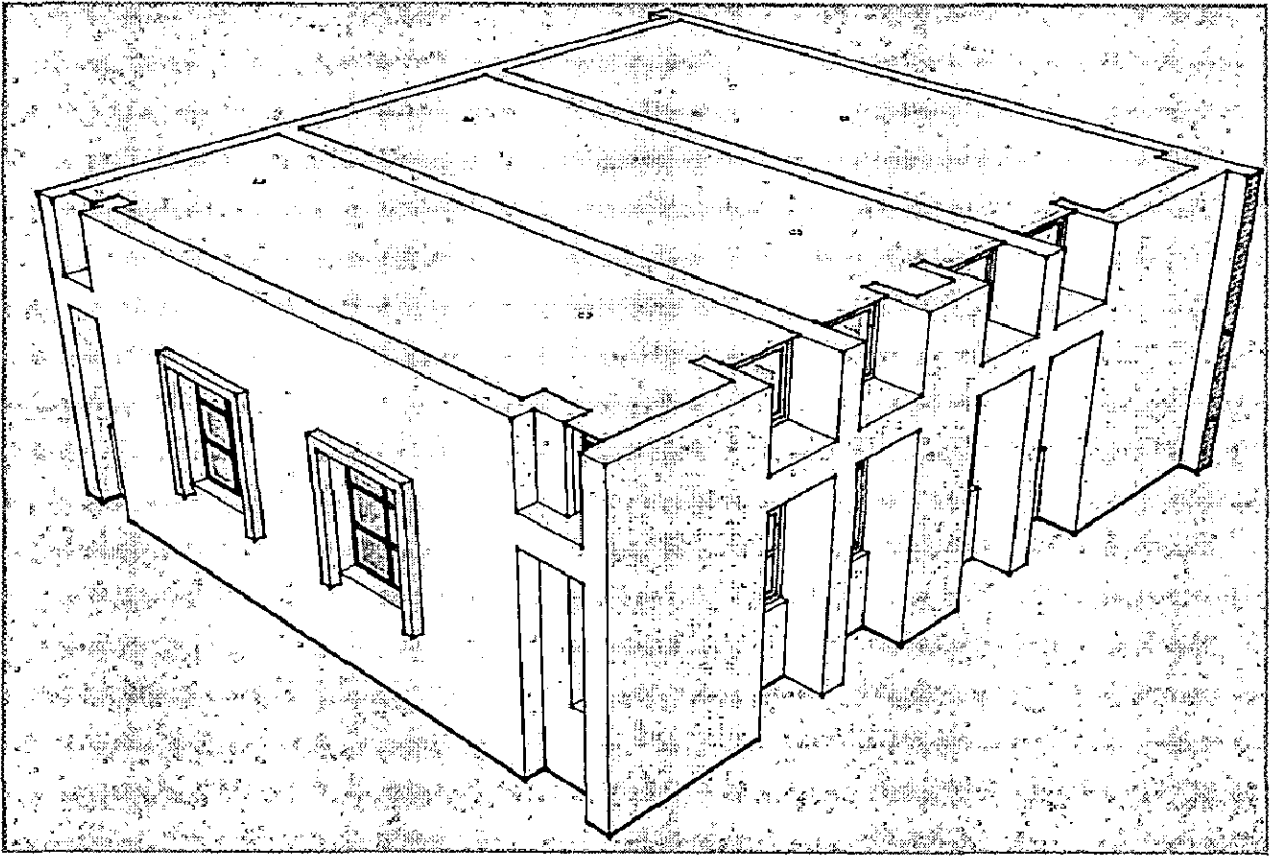
The floor area for Type 2 classroom is 44.2 sq.mts. Windows are provided on the North East and North West facing walls. Three different types of windows have been provided, as in type 1 classroom.

Window type 1 has 90cms sill height, 210cms lintel height and 90cms width. Window



type 2 has 75cms sill height, 210cms lintel height and 35cms width. Window type 3 has 75cms sill height, 210cms lintel height and 75cms width. Windows types 2 and 3 have ventilators above them that have 240cms sill height and 315cms lintel height. Total window area is 9.93 sq.mts, so window to floor area ratio is 22.46%.

**4.1.8. TYPES OF WINDOWS USED**



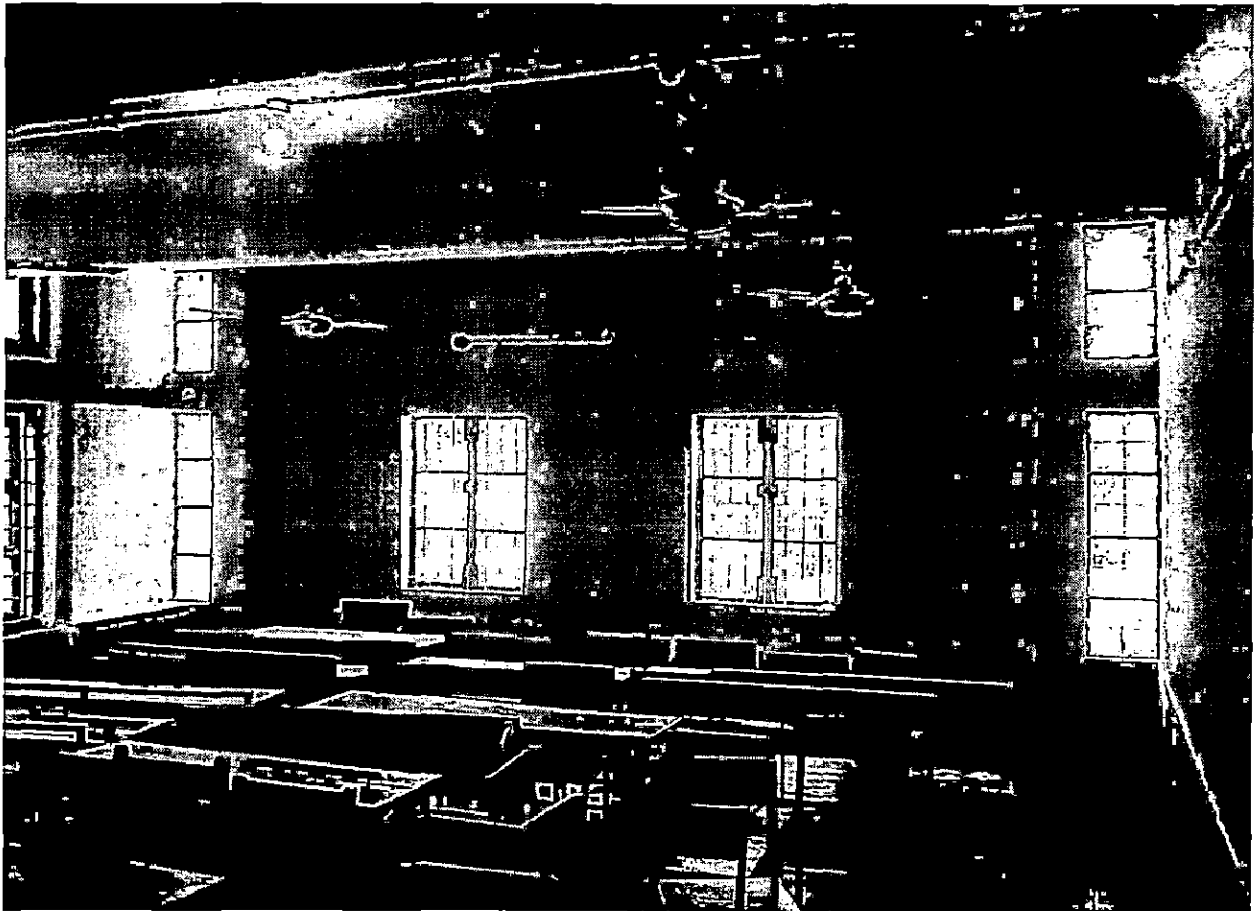
**4.1.9. EXTERIOR WALL FACADE ON WINDOW SIDES**

Windows on the North West wall are recessed. Only Type 2 windows on North East walls are recessed, type 1 windows have no sunshading. The class orientation is from North East to South West. Light enters the room from the right and rear of the classroom. Inner walls have been painted matte yellow up to sill height and white above it. No window blinds or curtains have been provided. Ceilings have been painted white and floor has a polished cement finish. Only two luminaires have been provided. Both are 100 Watt incandescent fixtures.

Again it is observed that the illuminance levels in this classroom are maximum near the windows and minimum at the farthest corner from the windows. The average illuminance is within the accepted range. Artificial lighting does not make a significant difference in the level of illuminance but it is not really necessary under normal sky conditions and normal operating hours of the school. Towards the corners of the room, light is slightly blocked by the user when he/she sits at the desk but it is not significant enough to impair tasks.

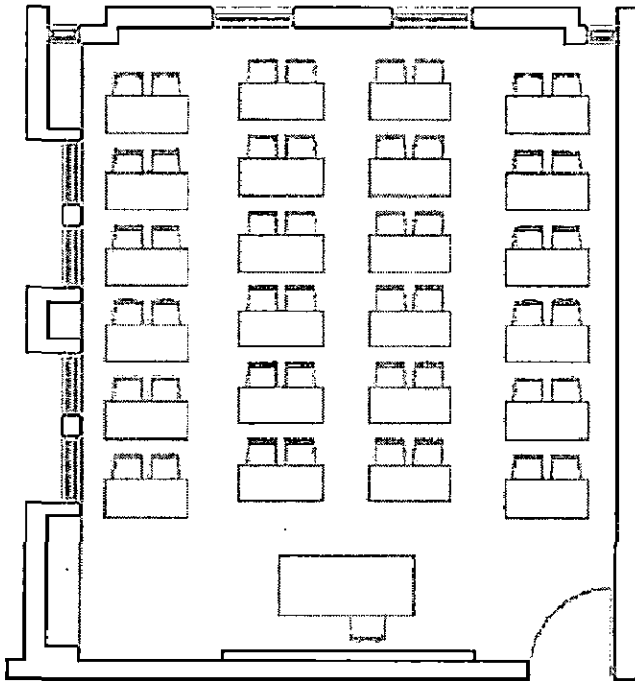
LIGHT LEVELS IN ROOMS (IN LUX)	DAYLIGHT	ARTIFICIAL LIGHT
BLACKBOARD	225	250
WINDOW CORNER	305, 815	325, 890
MIDDLE OF ROOM	245, 635	250, 655
FARTHEST CORNER	180, 425	225, 535
AVERAGE	384.07	424.78

TABLE 4.1.2. ILLUMINANCE LEVELS FOR TYPE 2 CLASSROOM

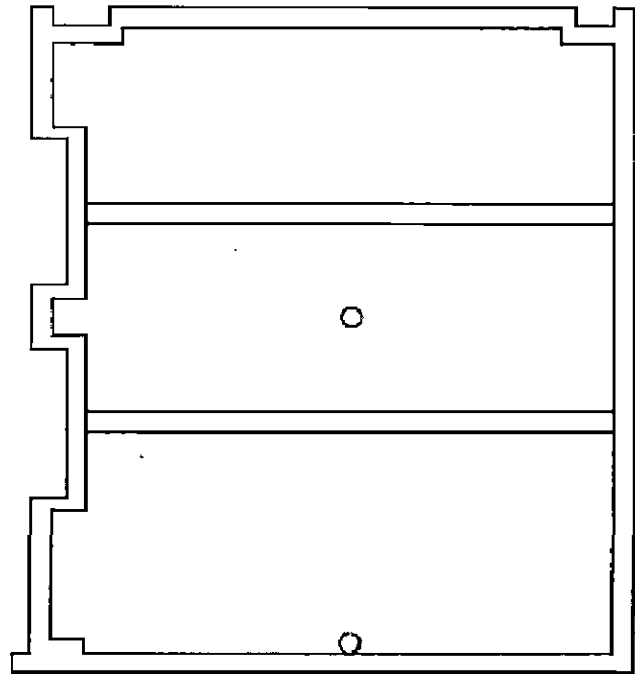


4.1.10. CLASSROOM IMAGE

**TYPE 3 CLASSROOM**

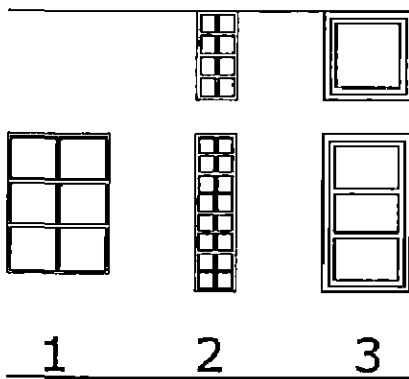


4.1.12. TYPE 3 CLASSROOM PLAN



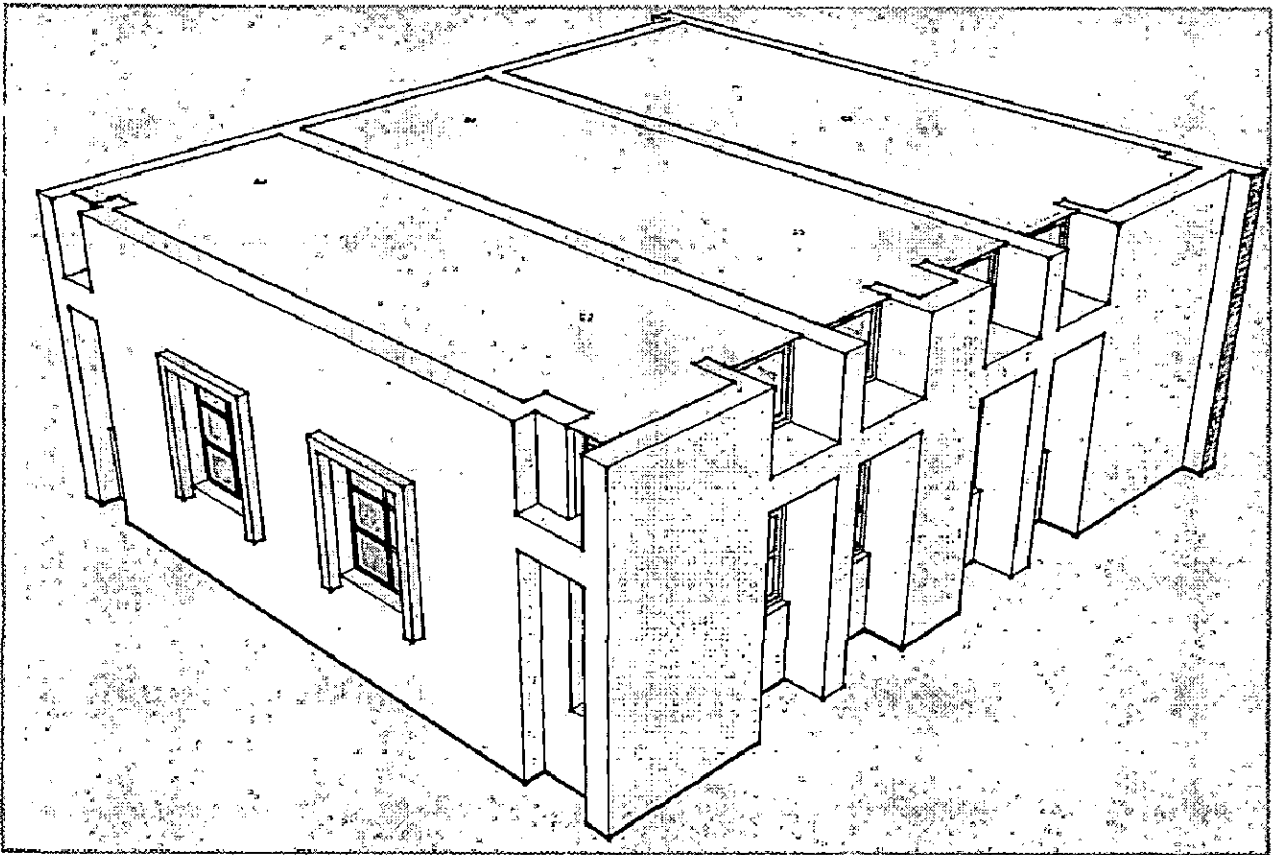
4.1.5. CEILING PLAN SHOWING FIXTURES

The floor area for Type 3 classroom is 44.2 sq.mts. Windows are provided on the South East and South West facing walls. Three different types of windows have been provided, as in type 1 classroom.



Window type 1 has 90cms sill height, 210cms lintel height and 90cms width. Window type 2 has 75cms sill height, 210cms lintel height and 35cms width. Window type 3 has 75cms sill height, 210cms lintel height and 75cms width. Windows types 2 and 3 have ventilators above them that have 240cms sill height and 315cms lintel height. Total window area is 9.93 sq.mts, so window to floor area ratio is 22.46%.

4.1.14. TYPES OF WINDOWS USED



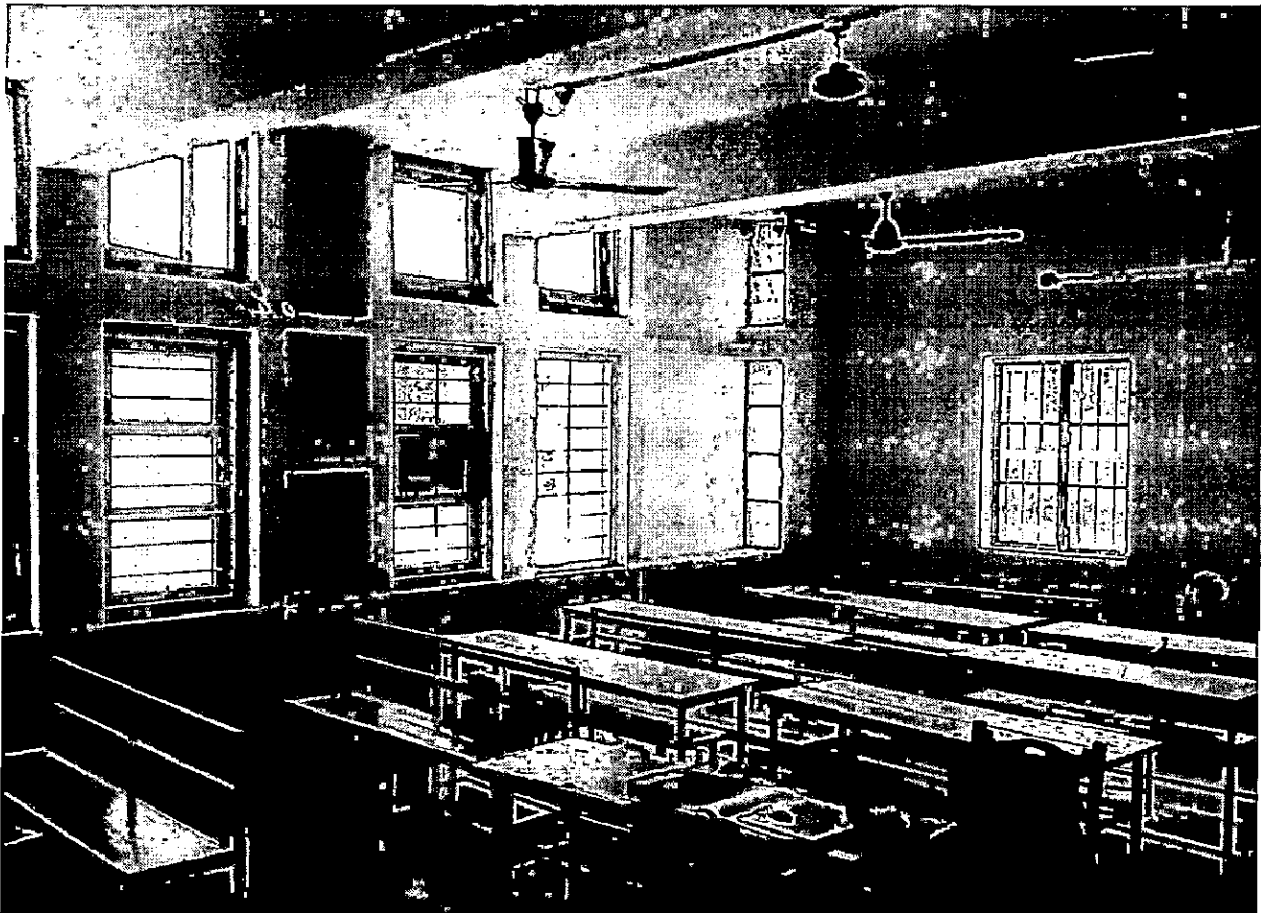
**4.1.15. EXTERIOR WALL FACADE ON WINDOW SIDES**

Windows on the South East wall are recessed. Only Type 2 windows on South West walls are recessed, type 1 windows have no sunshading. The class orientation is from South West to North East. Light enters the room from the right and rear of the classroom. Inner walls have been painted matte yellow up to sill height and white above it. No window blinds or curtains have been provided. Ceilings have been painted white and floor has a polished cement finish. Only two luminaires have been provided. Both are 100 Watt incandescent fixtures.

Here too it is observed that the illuminance levels in this classroom are maximum near the windows and minimum at the farthest corner from the windows. The average illuminance is within the accepted range. Artificial lighting does not make a significant difference in the level of illuminance but it is not really necessary under normal sky conditions and normal operating hours of the school. Towards the corners of the room, light is slightly blocked by the user when he/she sits at the desk but it is not significant enough to impair tasks.

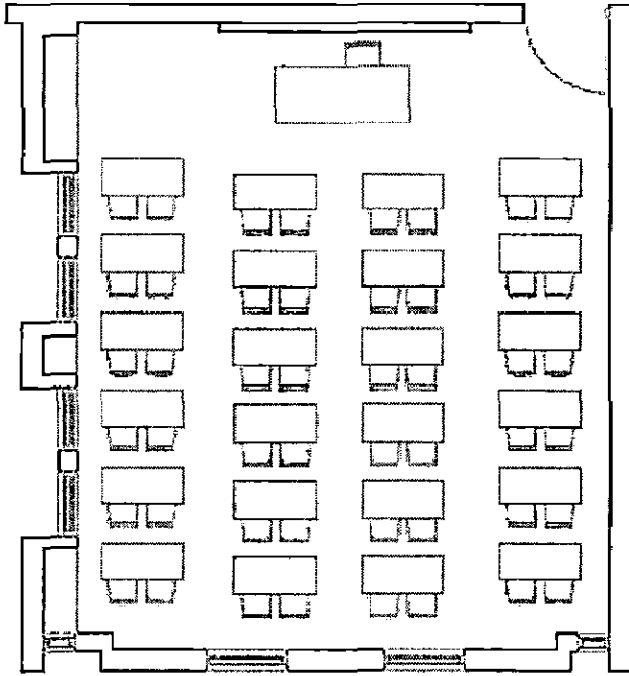
LIGHT LEVELS IN ROOMS (IN LUX)	DAYLIGHT	ARTIFICIAL LIGHT
BLACKBOARD	215	235
WINDOW CORNER	575, 690	580, 740
MIDDLE OF ROOM	315, 735	350, 820
FARTHEST CORNER	210, 475	260, 515
AVERAGE	436.32	475

TABLE 4.1.3 ILLUMINANCE LEVELS FOR TYPE 3 CLASSROOM

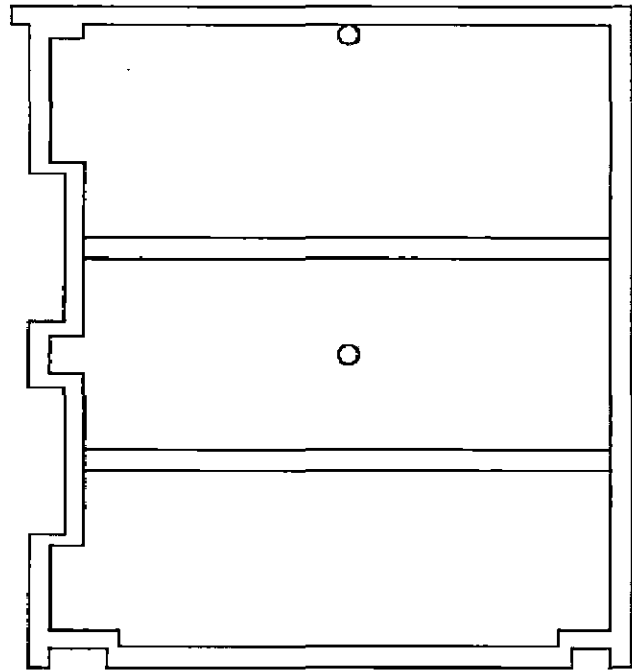


4.1.16. CLASSROOM IMAGE

**TYPE 4 CLASSROOM**

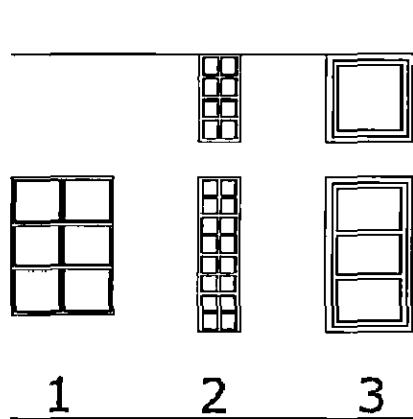


4.1.17. TYPE 4 CLASSROOM PLAN



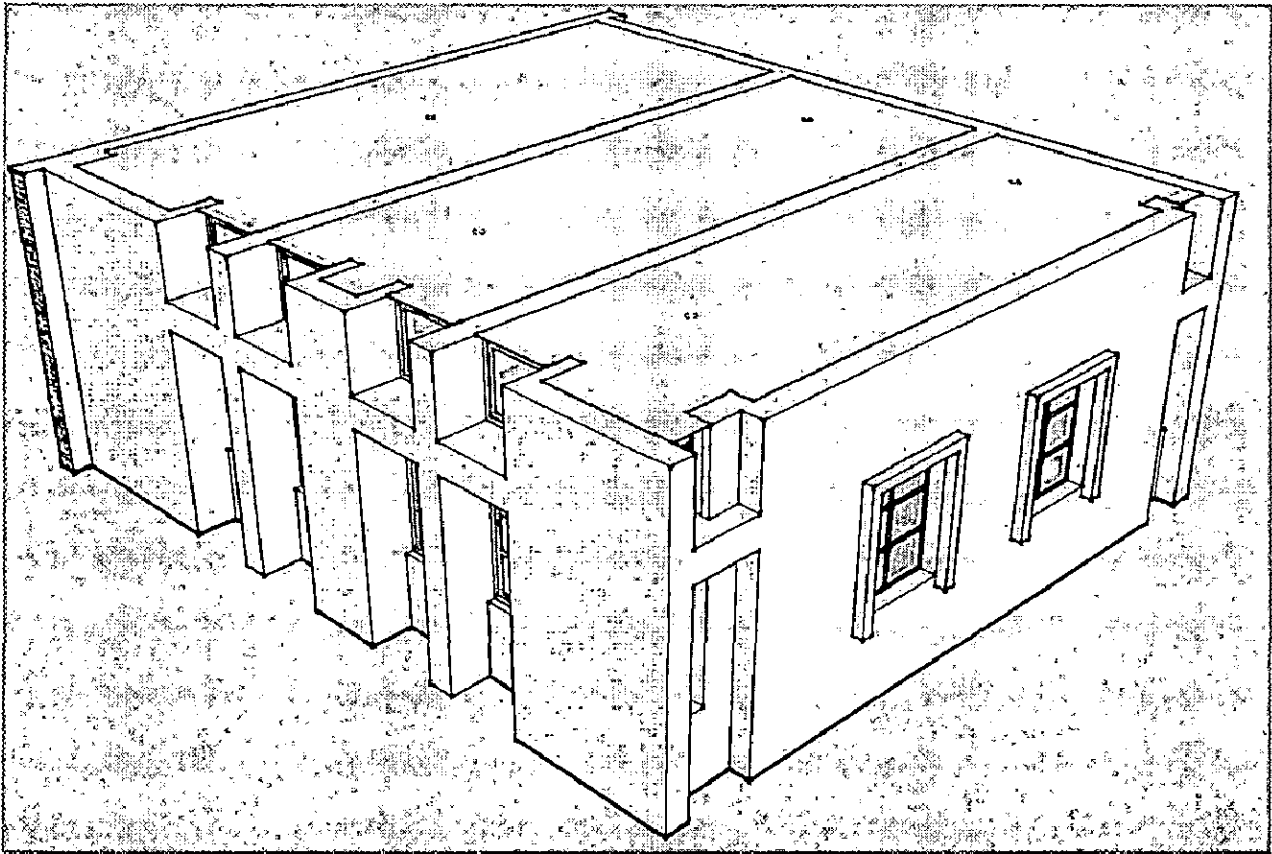
4.1.6 CEILING PLAN SHOWING FIXTURES

The floor area for Type 4 classroom is 44.2 sq.mts. Windows are provided on the North East and South East facing walls. Three different types of windows have been provided, as in type 1 classroom.



Window type 1 has 90cms sill height, 210cms lintel height and 90cms width. Window type 2 has 75cms sill height, 210cms lintel height and 35cms width. Window type 3 has 75cms sill height, 210cms lintel height and 75cms width. Windows types 2 and 3 have ventilators above them that have 240cms sill height and 315cms lintel height. Total window area is 9.93 sq.mts, so window to floor area ratio is 22.46%.

4.1.19 TYPES OF WINDOWS USED



**4.1.20. EXTERIOR WALL FACADE ON WINDOW SIDES**

Windows on the South East wall are recessed. Only Type 2 windows on North East walls are recessed, type 1 windows have no sunshading. The class orientation is from North East to South West. Light enters the room from the left and rear of the classroom. Inner walls have been painted matte yellow up to sill height and white above it. No window blinds or curtains have been provided. Ceilings have been painted white and floor has a polished cement finish. Only two luminaires have been provided. Both are 100 Watt incandescent fixtures.

Here too it is observed that the illuminance levels in this classroom are maximum near the windows and minimum at the farthest corner from the windows. The average illuminance is within the accepted range. Artificial lighting does not make a significant difference in the level of illuminance but it is not really necessary under normal sky conditions and normal operating hours of the school. Towards the corners of the room, light is slightly blocked by the user when he/she sits at the desk but it is not significant enough to impair tasks.



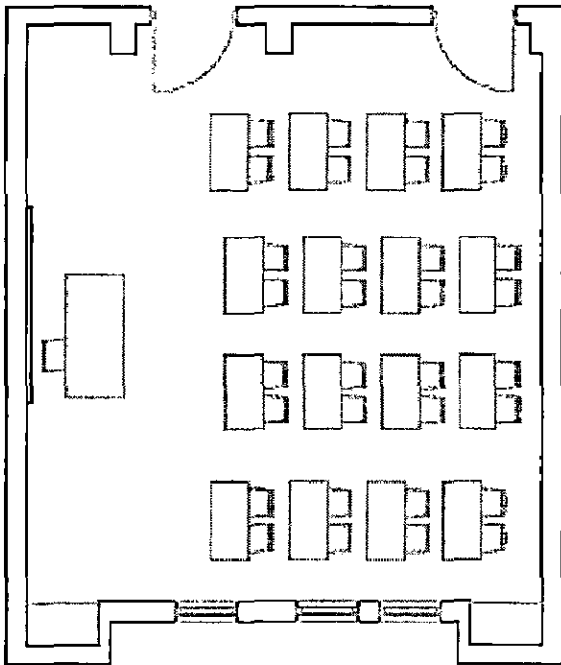
LIGHT LEVELS IN ROOMS (IN LUX)	DAYLIGHT	ARTIFICIAL LIGHT
BLACKBOARD	215	230
WINDOW CORNER	365, 645	350, 650
MIDDLE OF ROOM	260, 540	280, 540
FARTHEST CORNER	200, 645	220, 630
AVERAGE	389.5	393.57

TABLE 4.1.4. ILLUMINANCE LEVELS FOR TYPE 4 CLASSROOM

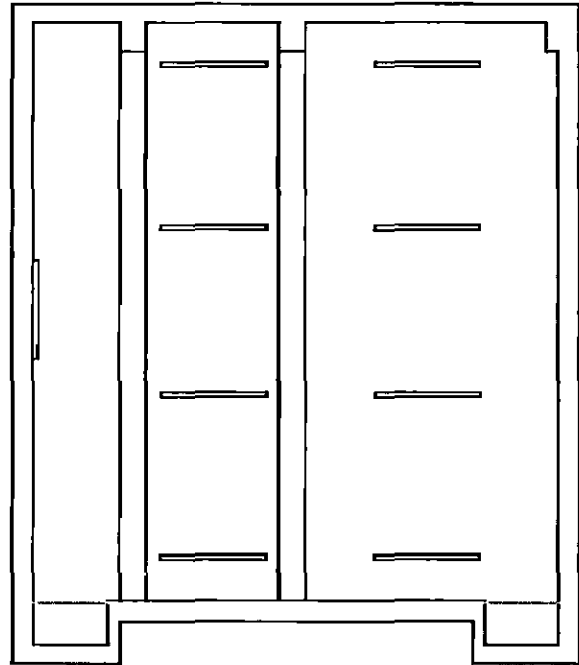


4.1.21. CLASSROOM IMAGE

**TYPE 5 CLASSROOM**

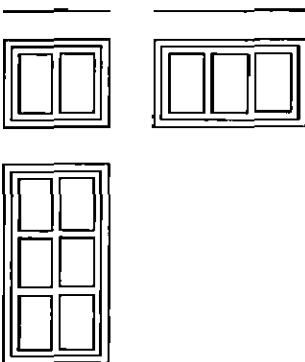


**4.1.22. TYPE 5 CLASSROOM PLAN**



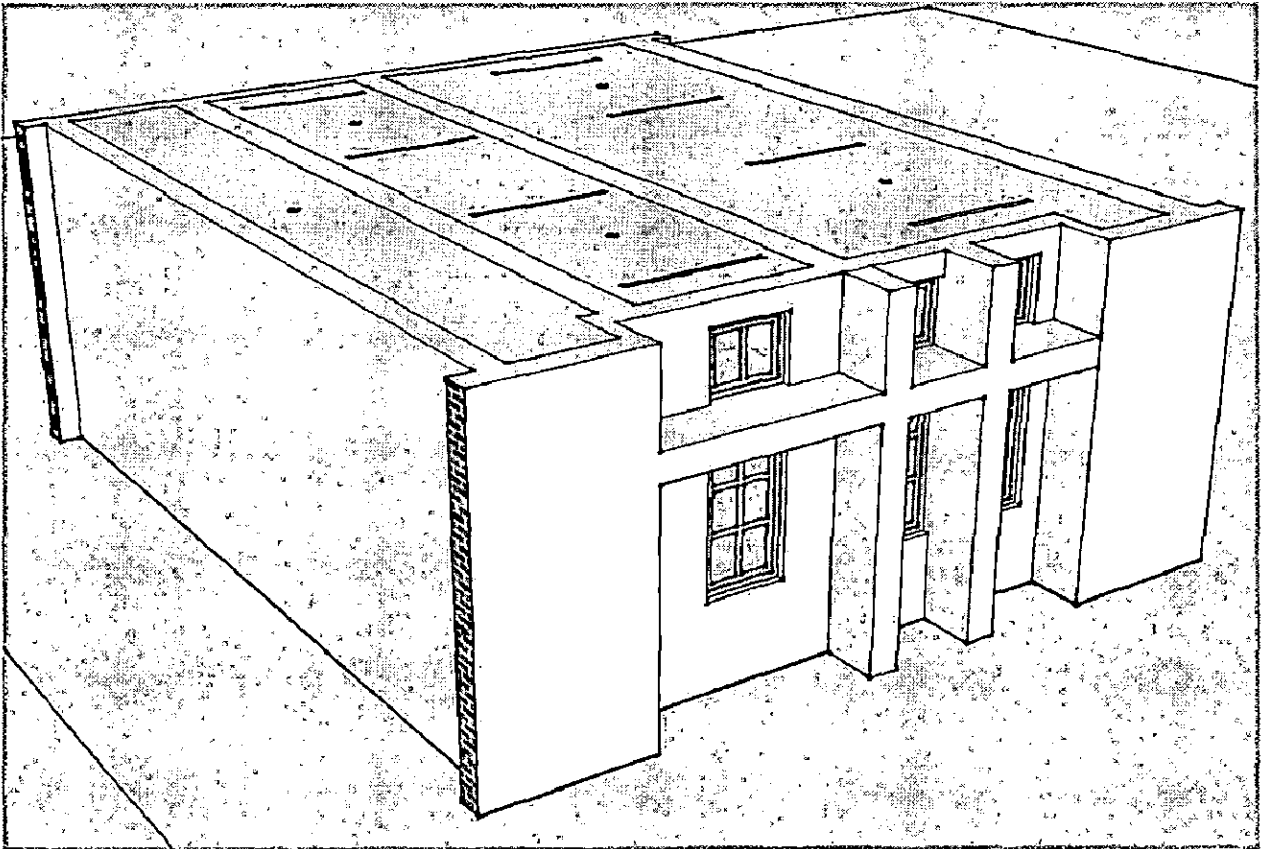
**4.1.23. CEILING PLAN SHOWING FIXTURES**

The floor area for Type 5 classroom is 42 sq.mts. Windows are provided on the South West facing wall. One type of window and one type of ventilator has been provided.



Window type 5 has 75cms sill height, 210cms lintel height and 70cms width. It has a ventilator on top with 235cms sill height, 295cms lintel height and 70cms width. Ventilator type 2 is provided over door on the North East wall. It has 235cms sill height, 295cms lintel height and 100cms width. Total window area is 5.29sq.mts and window to floor area ratio is 12.59%

**4.1.24. TYPES OF WINDOWS USED**



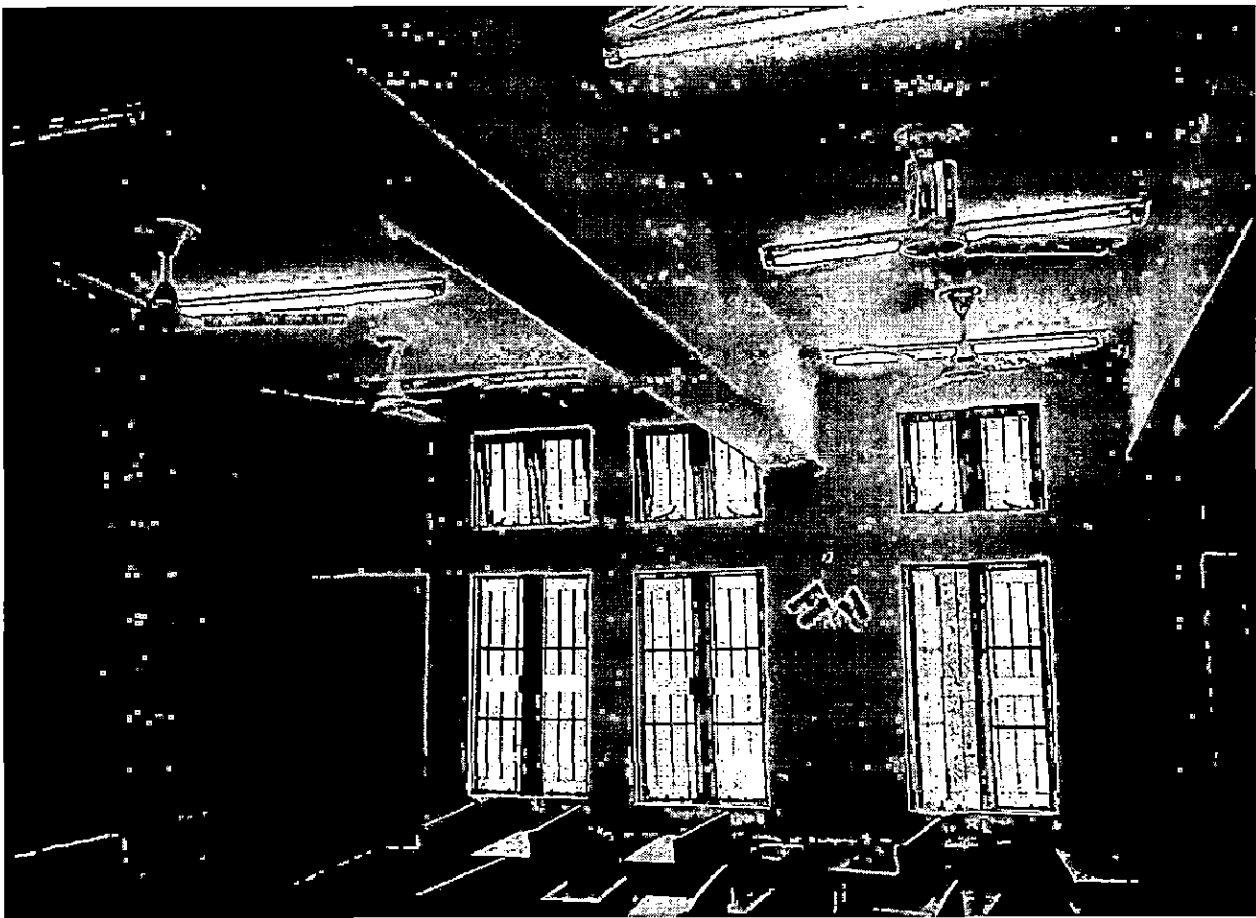
**4.1.25. EXTERIOR WALL FACADE ON WINDOW SIDES**

Windows on the South West wall are recessed. Ventilators in the North East wall open into the adjoining corridor so don't require separate sunshading. The class orientation is from South East to North West. Light enters the room mostly from the left side. Inner walls have been painted matte yellow up to sill height and white above it. No window blinds or curtains have been provided. Ceilings have been painted white and floor has a mosaic finish. Eight luminaires have been provided. All are 40 Watt tubelights.

Here too it is observed that the illuminance levels in this classroom are maximum near the windows and minimum at the farthest corner from the windows. However the illuminance levels really change if the door is left open during recordings. The average illuminance is within the accepted range. Artificial lighting makes some difference in the level of illuminance but it is not really necessary to switch on all lights under normal sky conditions and normal operating hours of the school.

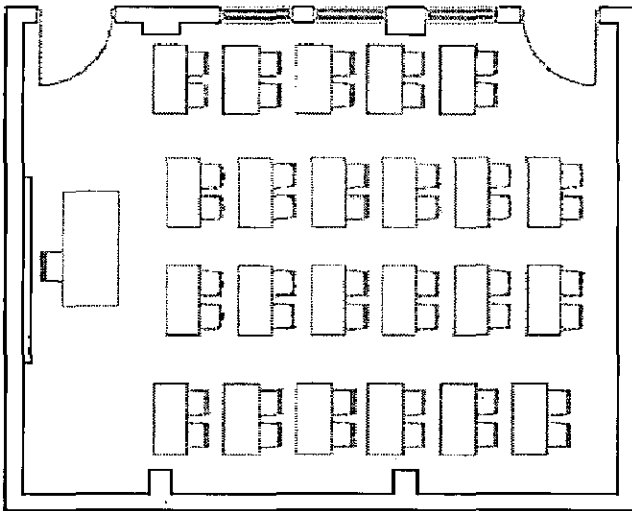
LIGHT LEVELS IN ROOMS (IN LUX)	DAYLIGHT	ARTIFICIAL LIGHT
BLACKBOARD	145	170
WINDOW CORNER	500, 390	620, 475
MIDDLE OF ROOM	135, 105	285, 185
FARTHEST CORNER	290, 70	390, 135
AVERAGE	221.89	306.71

TABLE 4.1.5. ILLUMINANCE LEVELS FOR TYPE 5 CLASSROOM

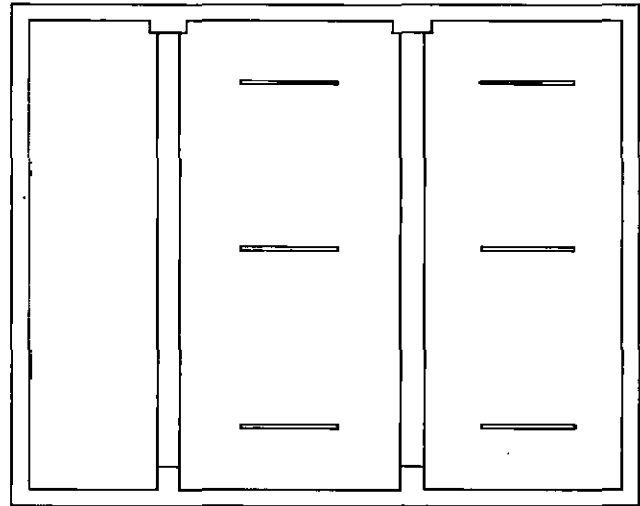


4.1.26. CLASSROOM IMAGE

**TYPE 6 CLASSROOM**

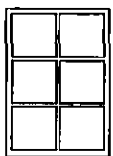


**4.1.27. TYPE 6 CLASSROOM PLAN**



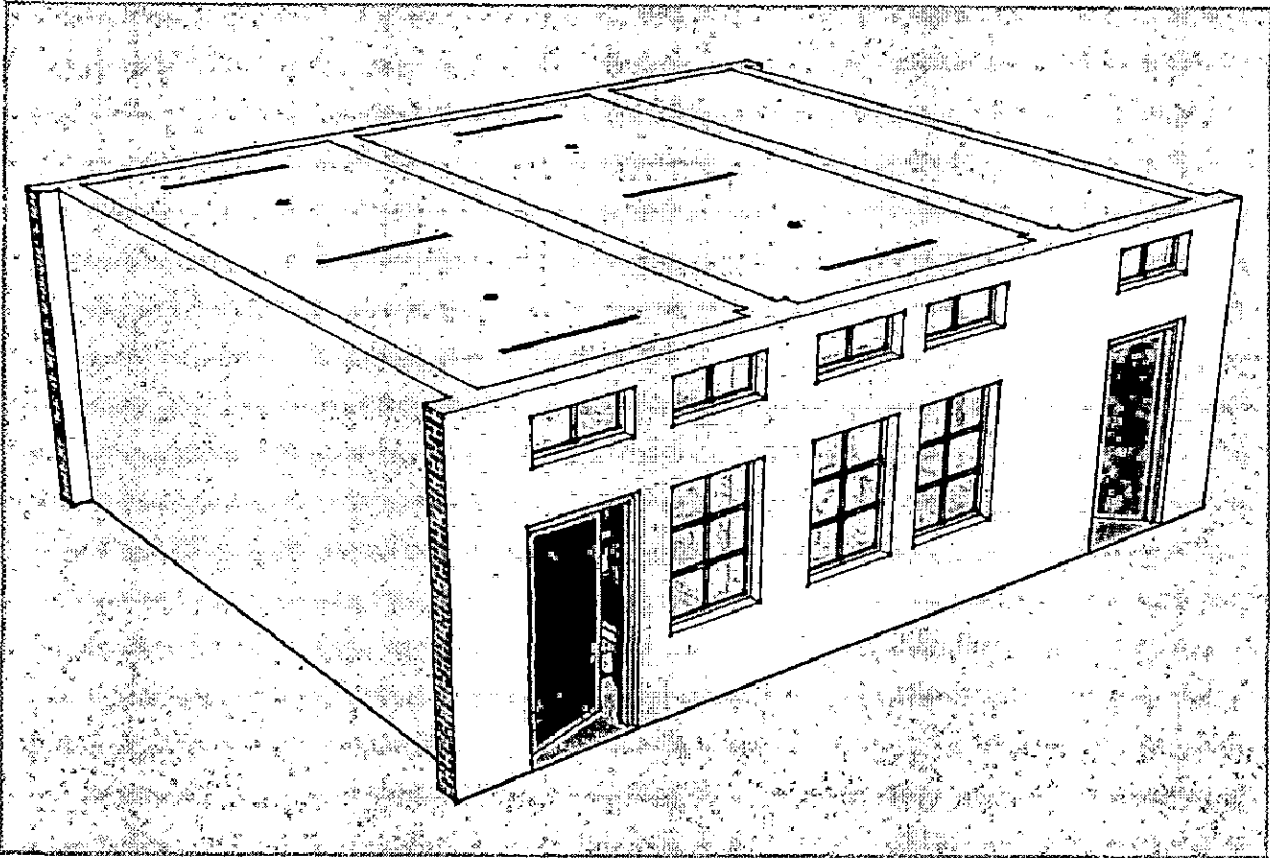
**4.1.28. CEILING PLAN SHOWING FIXTURES**

The floor area for Type 5 classroom is 42 sq.mts. Windows are provided on the South West facing wall. One type of window and one type of ventilator has been provided.



Window type 6 has 75cms sill height, 210cms lintel height and 90cms width. It has a ventilator on top with 235cms sill height, 295cms lintel height and 70cms width. Ventilator type 2 is provided over door on the North East wall. It has 255cms sill height, 295cms lintel height and 90cms width. Total window area is 5.31 sq.mts and window to floor area ratio is 11.49%

**4.1.29 TYPES OF WINDOWS USED**



**4.1.30. EXTERIOR WALL FACADE ON WINDOW SIDES**

Windows are on the North West wall. No separate shading is built for these as the windows open into a single side corridor. The class orientation is from North East to South West. Light enters the room from the right side. Inner walls have been painted white all the way. No window blinds or curtains have been provided. Ceilings have been painted white and floor has a mosaic finish. Six luminaires have been provided. All are 40 Watt tubelights.

Here too it is observed that the illuminance levels in this classroom are maximum near the windows and minimum at the farthest corner from the windows. The average illuminance is below the accepted range. Artificial lighting makes a significant difference in the level of illuminance but not all the fixtures are operational. This is one of the darkest classrooms in the selected examples.

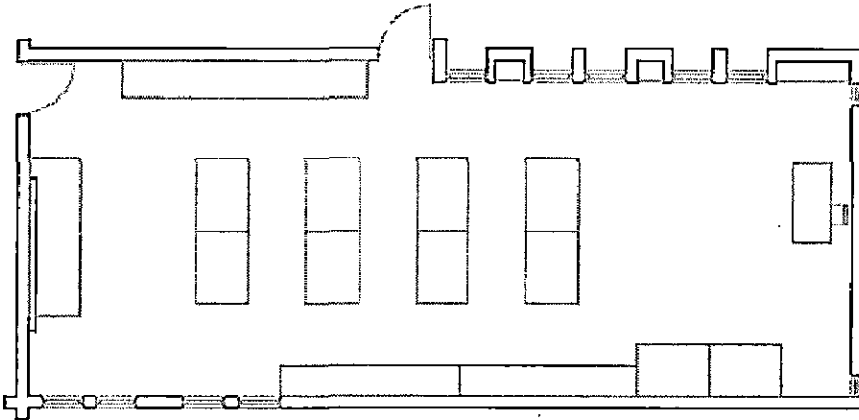
LIGHT LEVELS IN ROOMS (IN LUX)	DAYLIGHT	ARTIFICIAL LIGHT
BLACKBOARD	135	170
WINDOW CORNER	385, 240	410, 265
MIDDLE OF ROOM	170, 100	205, 140
FARTHEST CORNER	115, 75	120, 90
AVERAGE	165.71	190

TABLE 4.1.6. ILLUMINANCE LEVELS FOR TYPE 6 CLASSROOM

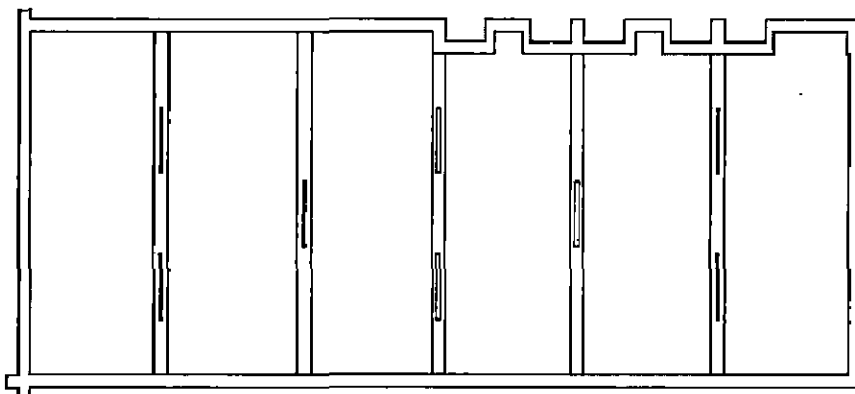


4.1.31. CLASSROOM IMAGE

**TYPE 1 LABORATORY**

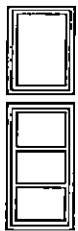


**4.1.32. TYPE 1 LABORATORY FLOOR PLAN**



**4.1.33. CEILING PLAN SHOWING FIXTURES**

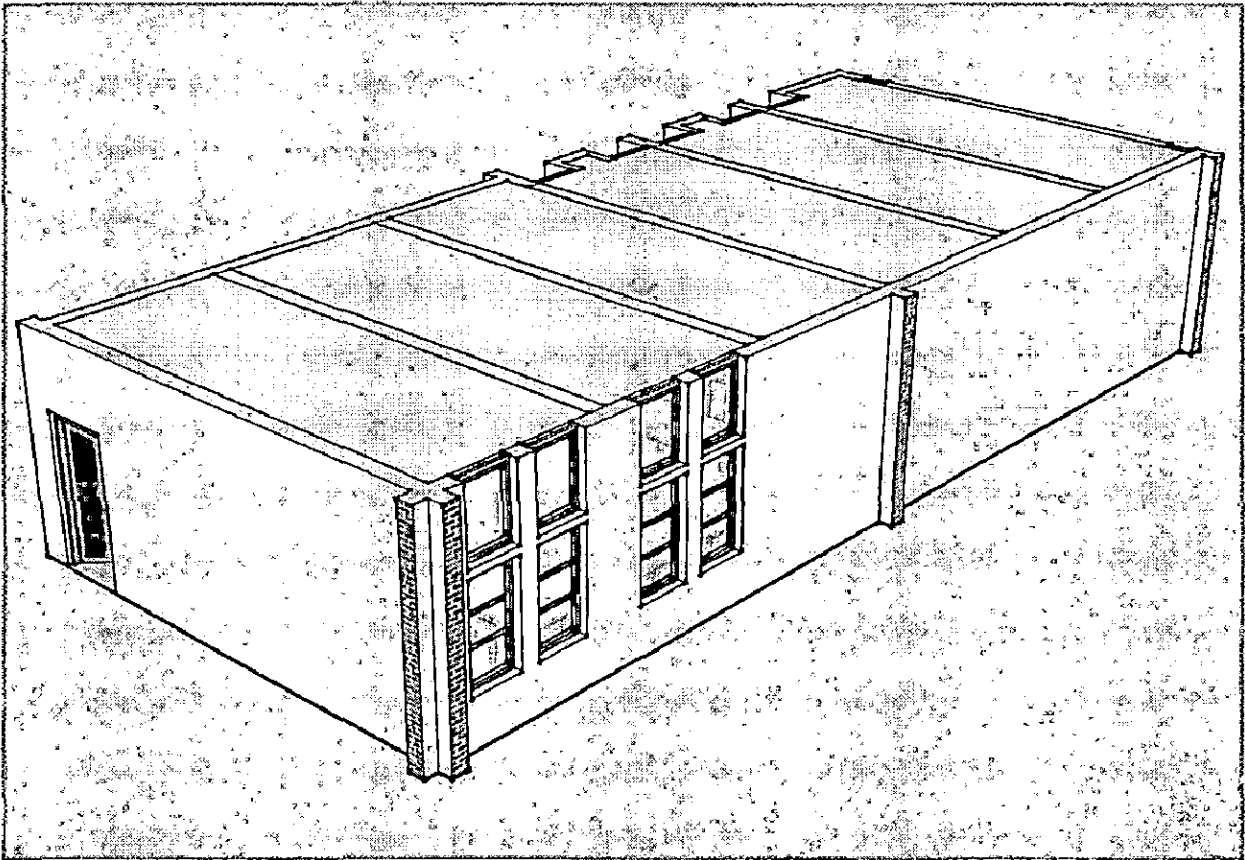
The floor area for Type 1 laboratory is 94.5 sq.mts. Windows are provided on the North West and South East facing walls. One type of window has been provided.



Window type 7 has 65cms sill height, 210cms lintel height and 75cms width. It has a ventilator on top with 220cms sill height, 315cms lintel height and 75cms width. Total window area is 17sq.mts and window to floor area ratio is 17.98%

**4.1.34. TYPES OF WINDOWS USED**





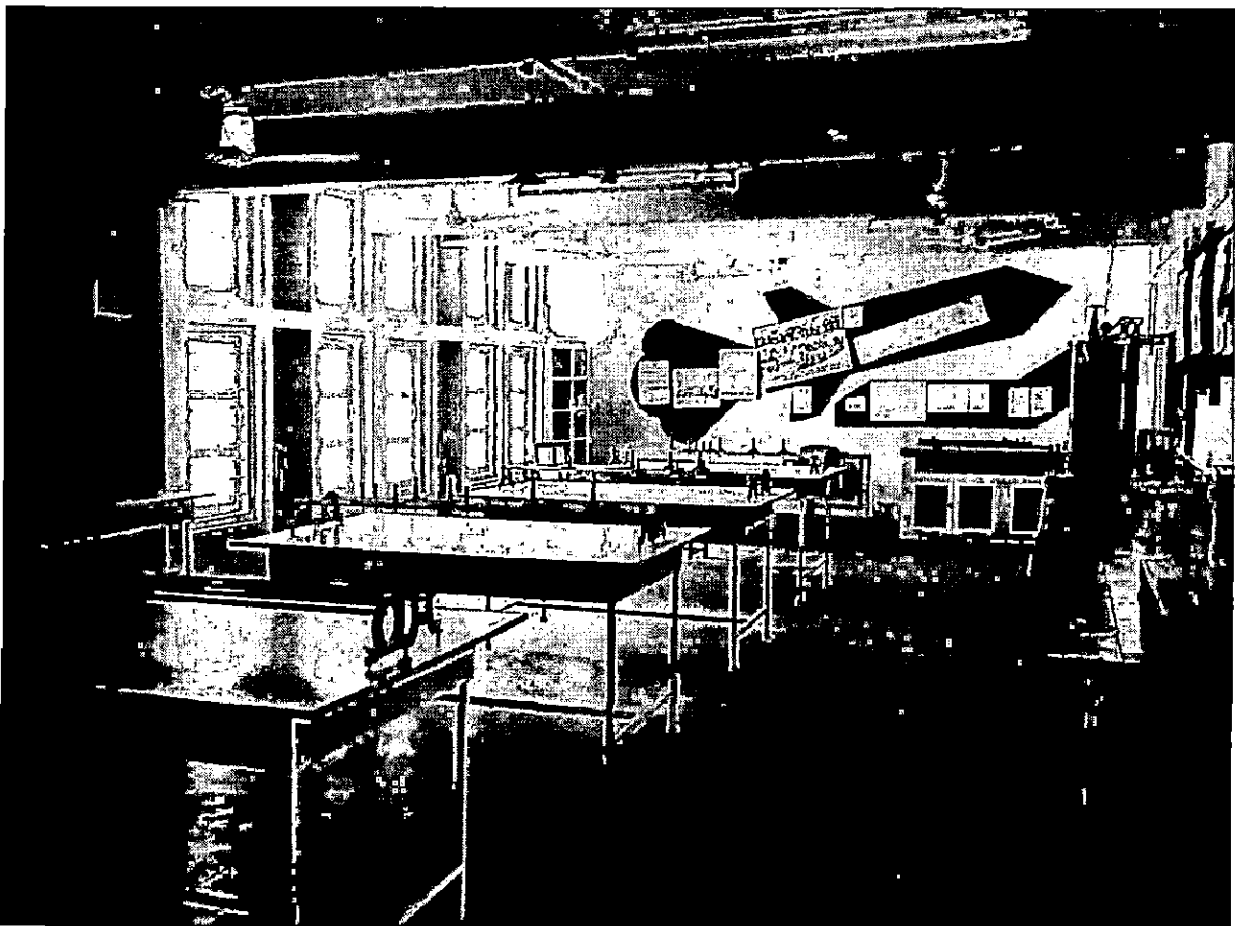
**4.1.35. EXTERIOR WALL FACADE ON WINDOW SIDES**

Windows are on the North West and South East walls. The South East facing windows are recessed. North West facing windows open into a single side corridor so require no separate shading. The laboratory orientation is from South West to North East. Light enters the room from both the right and left sides. Inner walls have been painted light cream. No window blinds or curtains have been provided. Ceilings have been painted white and floor has a mosaic finish. Eight luminaires have been provided. All are 40 Watt tubelights.

The maximum illuminance levels in this space are near the diagonally opposite corners where windows are located and minimum towards the room centre. The average illuminance is within the accepted range. Artificial lighting makes a significant difference in distribution of light more evenly.

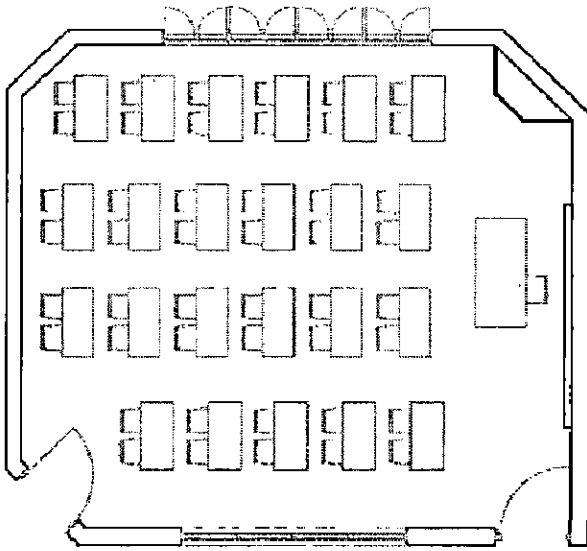
LIGHT LEVELS IN ROOMS (IN LUX)	DAYLIGHT	ARTIFICIAL LIGHT
BLACKBOARD	125	195
WINDOW CORNER	235, 200	260, 265
MIDDLE OF ROOM	100, 400	260, 450
FARTHEST CORNER	55, 545	125, 605
AVERAGE	225.28	293.14

TABLE 4.1.7. ILLUMINANCE LEVELS FOR TYPE 1 LABORATORY

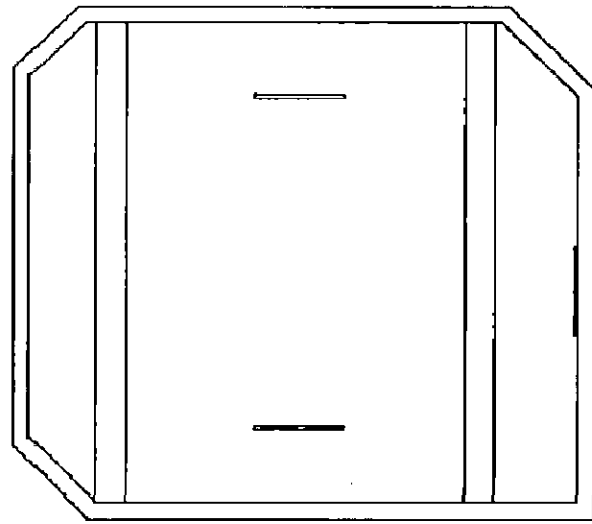


4.1.36. LABORATORY IMAGE

**4.2 OBSERVATIONS FOR SCHOOL 2 – FATHER AGNEL SCHOOL NOIDA  
TYPE 1 CLASSROOM**

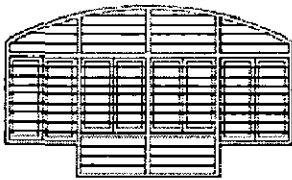


**4.2.1. TYPE 1 CLASSROOM FLOOR PLAN**

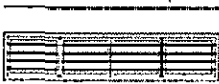


**4.2.2. CEILING PLAN SHOWING FIXTURES**

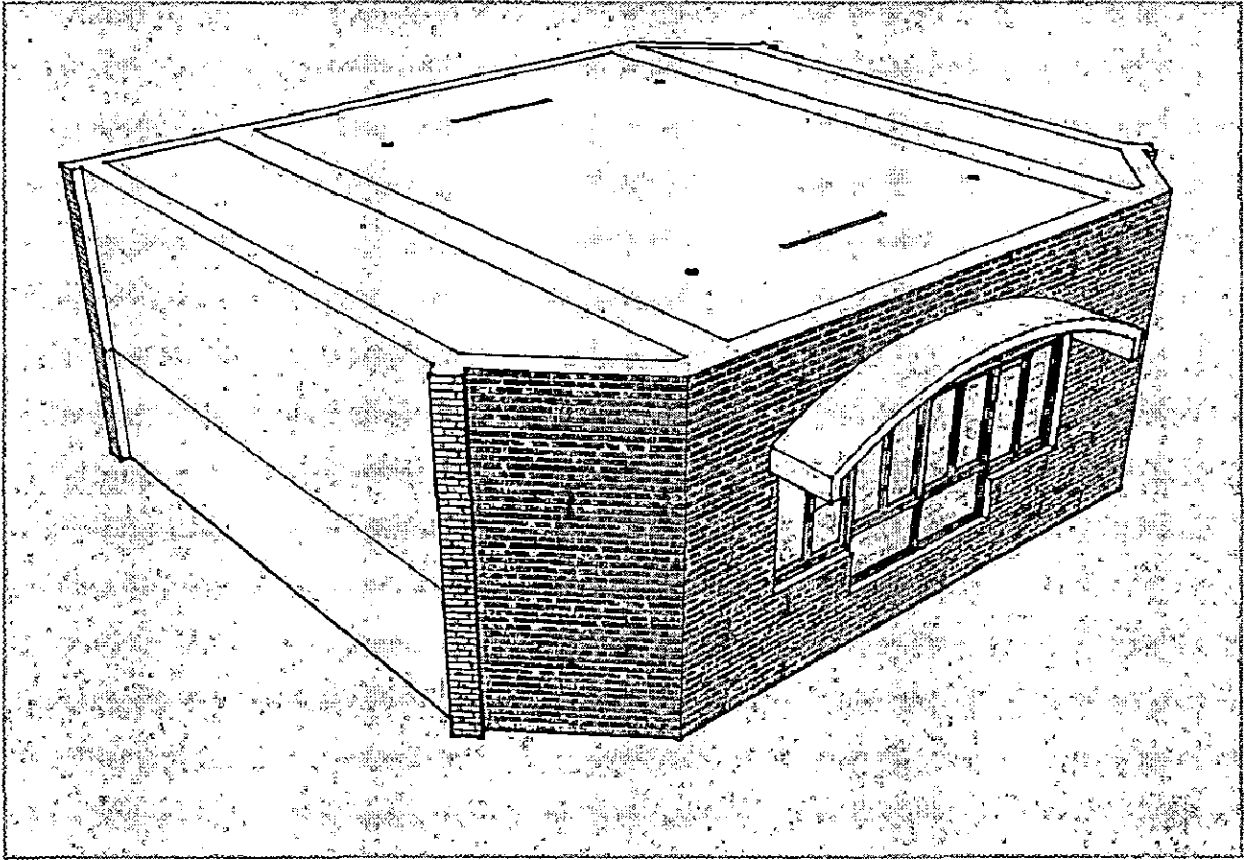
The floor area for Type 1 classroom is 47.5 sq.mts. Window is provided on the North facing wall. One type of window and one ventilator has been provided.



Window type 1 has two sill heights at 50cms and 90cms, top of the window is arched. The arch height is 260cms. Width is 360cms. South wall has a ventilator with 210cms sill height, 275cms lintel height and width 300cms. Total window area is 8.46sq.mts and window to floor area ratio is 17.81%



**4.2.3. TYPES OF WINDOWS USED**



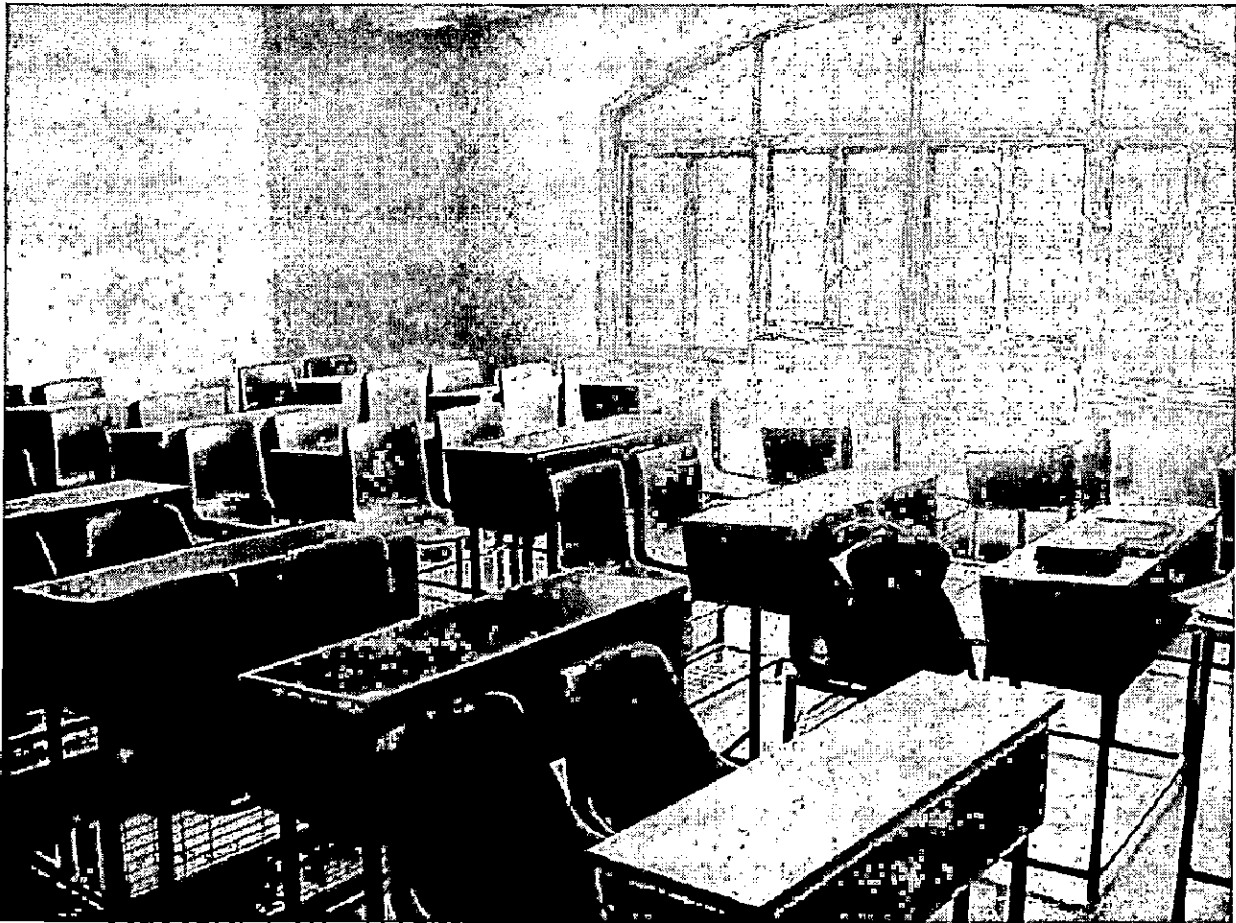
#### 4.2.4. EXTERIOR WALL FACADE ON WINDOW SIDES

Window is on the North facing walls. It has been provided with a 60cm sunshade. South wall is provided with a ventilator that opens into the double side corridor. The classroom orientation is from West to East. Light enters the room from the left side. Inner walls have been painted light pink in gloss finish up to 120cms and matte finish above. No window blinds or curtains have been provided. Ceilings have been painted white and floor has a mosaic finish. Three luminaires have been provided. All are 40 Watt tubelights.

The illuminance levels in this space are maximum near the window sides and minimum towards the far corner. The average illuminance is within the accepted range. Artificial lighting doesn't make a significant difference in illuminance levels.

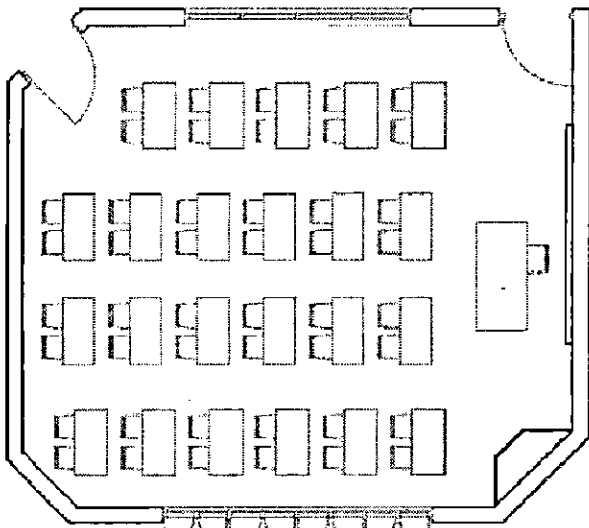
LIGHT LEVELS IN ROOMS (IN LUX)	DAYLIGHT	ARTIFICIAL LIGHT
BLACKBOARD	120	155
WINDOW CORNER	850, 400	935, 405
MIDDLE OF ROOM	300, 200	315, 235
FARTHEST CORNER	95, 100	150, 125
AVERAGE	280.25	314.85

TABLE 4.2.1. ILLUMINANCE LEVELS FOR TYPE 1 CLASSROOM

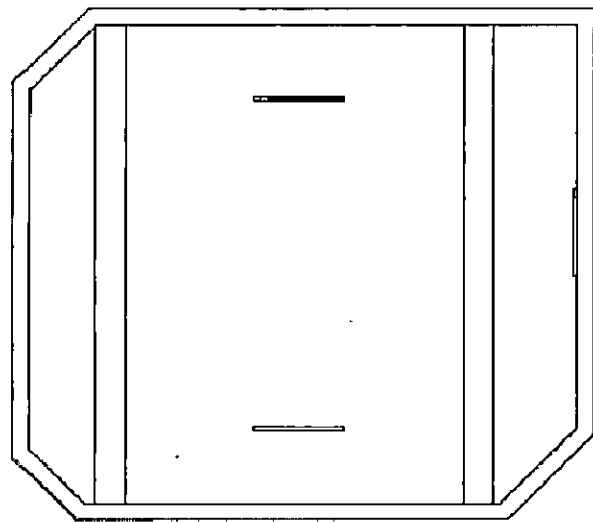


4.2.5. CLASSROOM IMAGE

**TYPE 2 CLASSROOM**

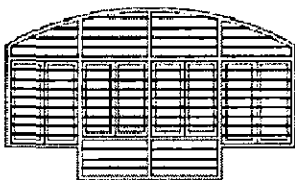


**4.2.6. TYPE 2 CLASSROOM FLOOR PLAN**



**4.2.7. CEILING PLAN SHOWING FIXTURES**

The floor area for Type 2 classroom is 47.5 sq.mts. Window is provided on the South facing wall. One type of window and one ventilator has been provided.



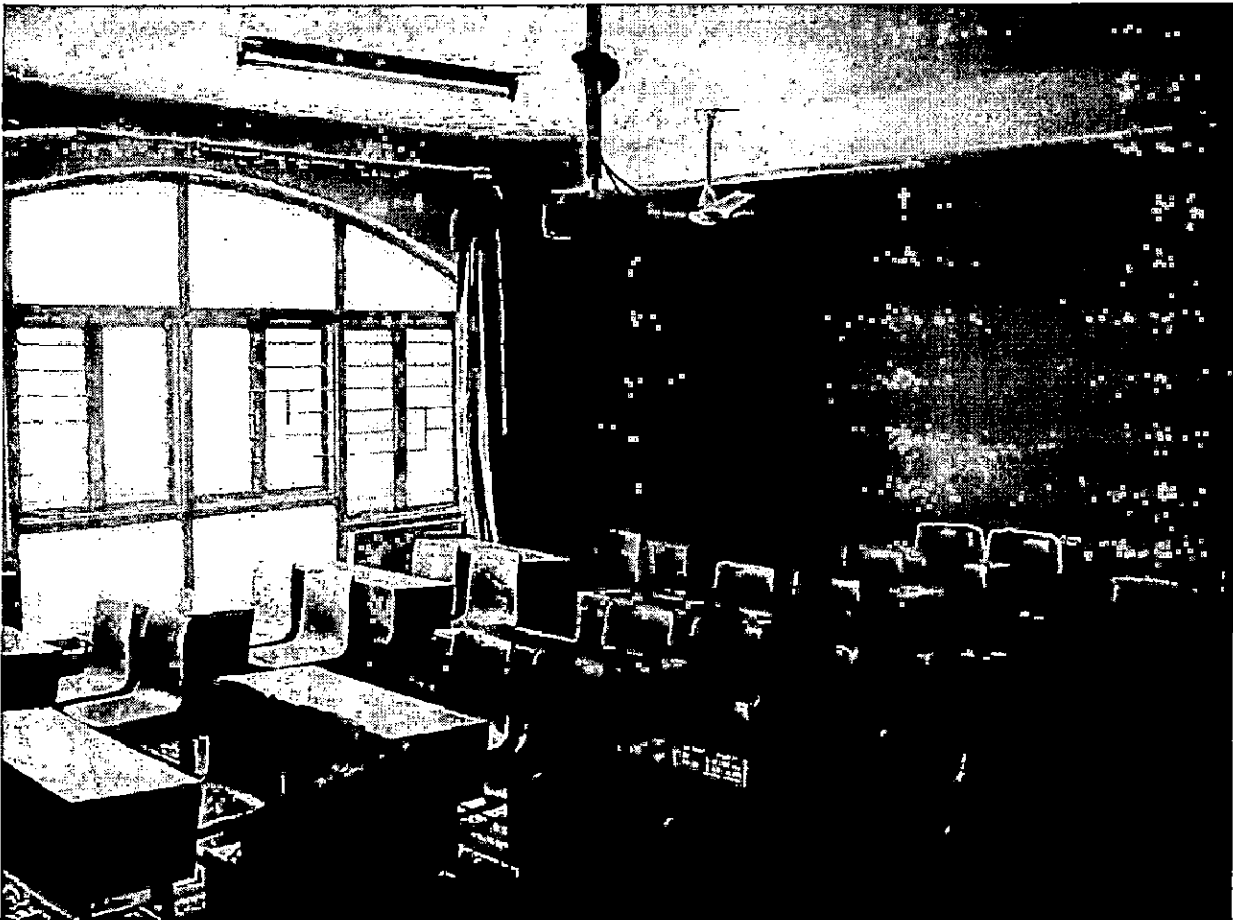
Window type 1 has two sill heights at 50cms and 90cms, top of the window is arched. The arch height is 260cms, width is 360cms. North wall has a ventilator with 210cms sill height, 275cms lintel height and width is 300cms. Total window area is 8.46sq.mts and window to floor area ratio is 17.81%



**4.2.8. TYPES OF WINDOWS USED**

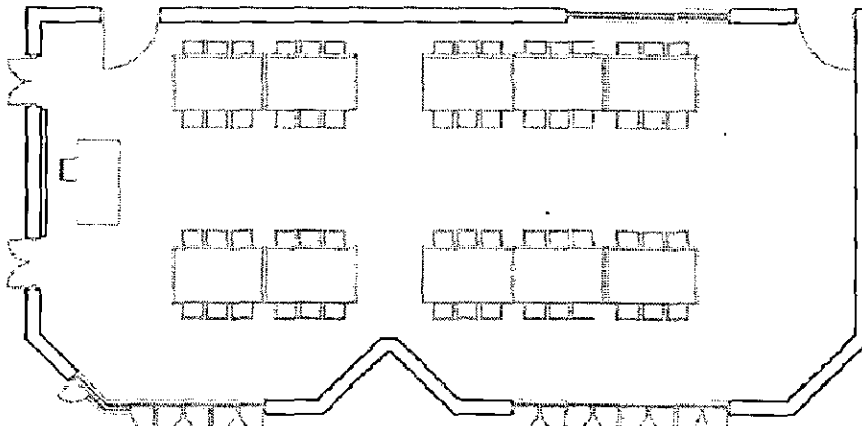
LIGHT LEVELS IN ROOMS (IN LUX)	DAYLIGHT	ARTIFICIAL LIGHT
BLACKBOARD	150	190
WINDOW CORNER	855, 335	925, 350
MIDDLE OF ROOM	205, 255	250, 270
FARTHEST CORNER	85, 165	125, 235
AVERAGE	278.21	318.25

TABLE 4.2.2. ILLUMINANCE LEVELS FOR TYPE 2 CLASSROOM

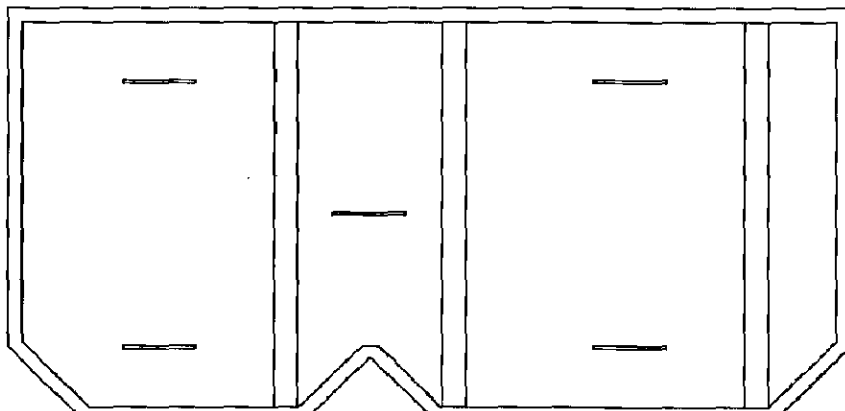


4.2.10. CLASSROOM IMAGE

**TYPE 1 LABORATORY**

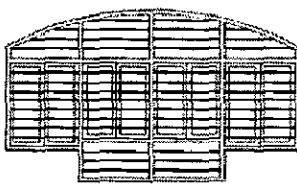


**4.2.11. TYPE 1 LABORATORY FLOOR PLAN**



**4.2.12. CEILING PLAN SHOWING FIXTURES**

The floor area for Type 1 laboratory is 86.4 sq.mts. Window is provided on the South facing wall. One window same as in type 1 classroom and one ventilator has been provided.



Window type 1 has two sill heights at 50cms and 90cms, top of the window is arched. The arch height is 260cms. Width is 360cms North wall has a ventilator with 210cms sill height, 275cms lintel height and width 270cms. Total window area is 14.77sq.mts and window to floor area ratio is 17.09%

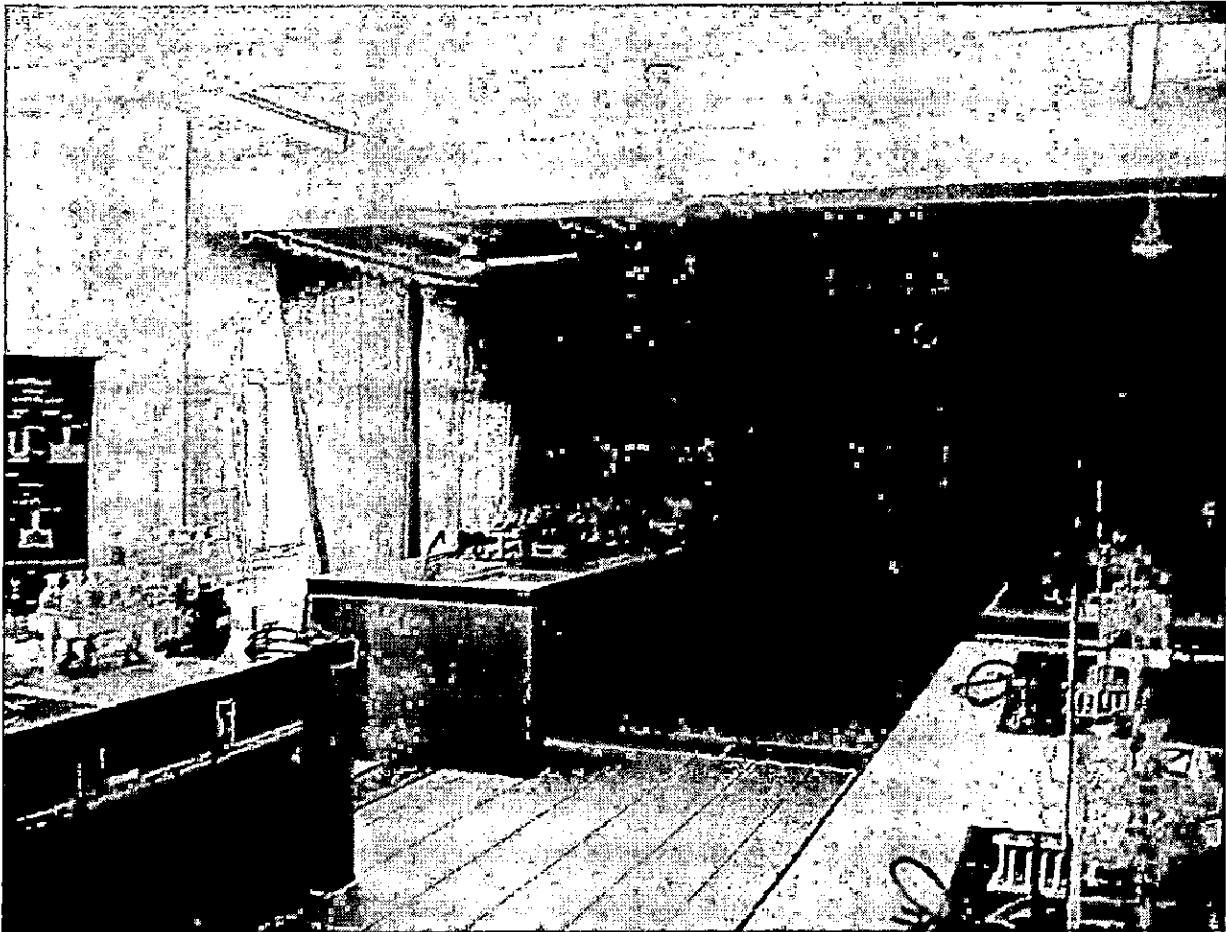


**4.2.13. TYPES OF WINDOWS USED**



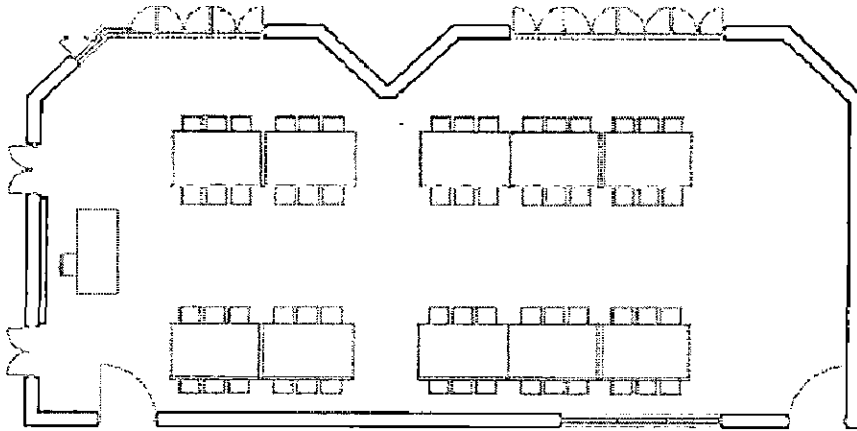
LIGHT LEVELS IN ROOMS (IN LUX)	DAYLIGHT	ARTIFICIAL LIGHT
BLACKBOARD	290	55
WINDOW CORNER	1120, 1465	60, 90
MIDDLE OF ROOM	500, 420	65, 85
FARTHEST CORNER	135, 160	60, 105
AVERAGE	555.07	70.57

TABLE 4.2.3 ILLUMINANCE LEVELS FOR TYPE 1 LABORATORY

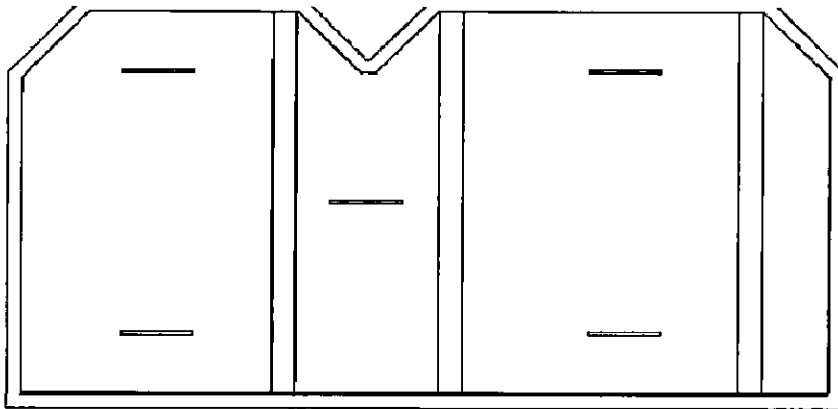


4.2.15. LABORATORY IMAGE

**TYPE 2 LABORATORY**

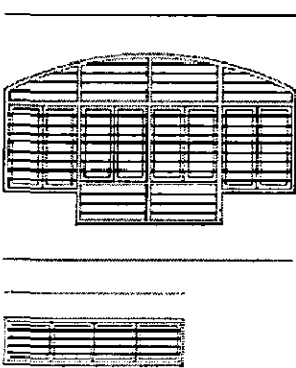


**4.2.16. TYPE 2 LABORATORY FLOOR PLAN**



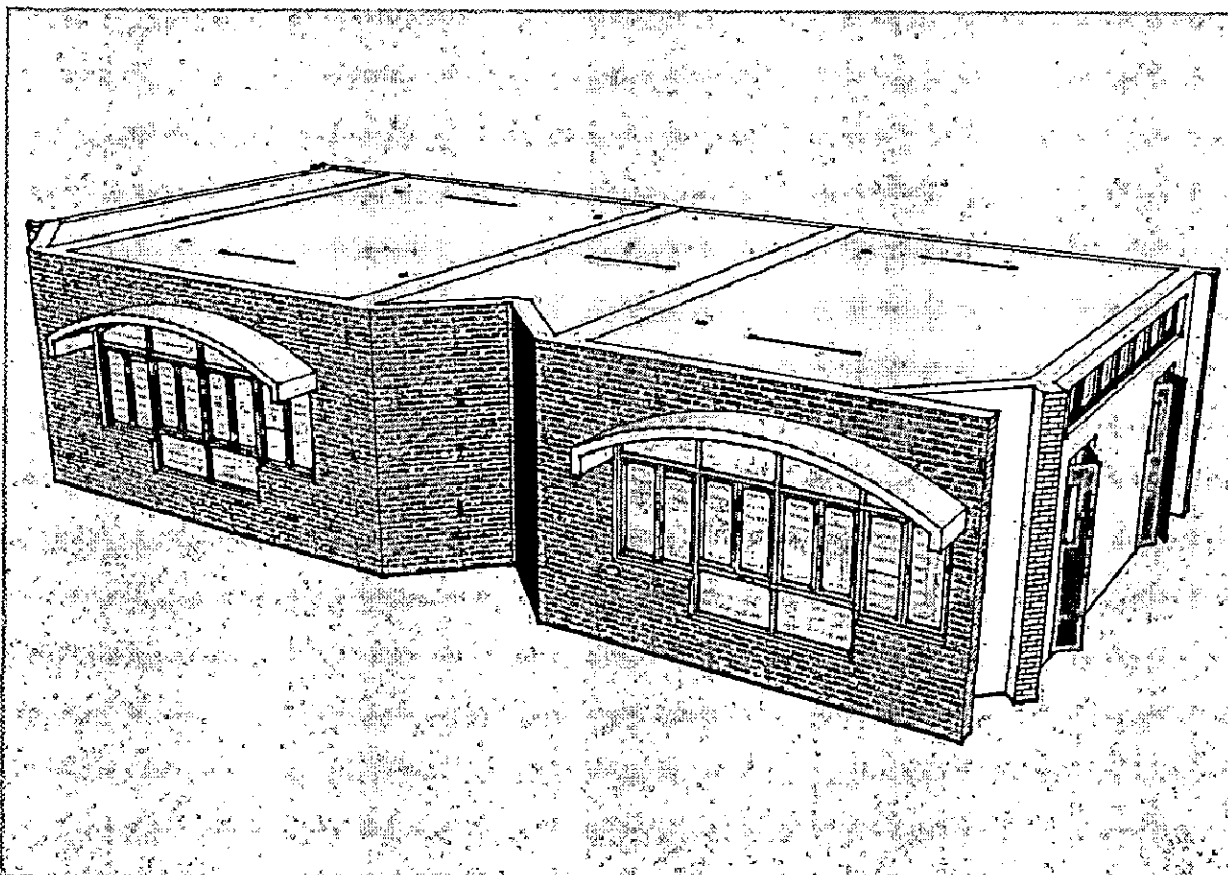
**4.2.17. CEILING PLAN SHOWING FIXTURES**

The floor area for Type 2 laboratory is 86.4 sq.mts. Window is provided on the North facing wall. One window same as in type 1 classroom and one ventilator has been provided.



Window type 1 has two sill heights at 50cms and 90cms, top of the window is arched. The arch height is 260cms. Width is 360cms North wall has a ventilator with 210cms sill height, 275cms lintel height and width 270cms. Total window area is 14.77sq.mts and window to floor area ratio is 17.09%

**4.2.18. TYPES OF WINDOWS USED**



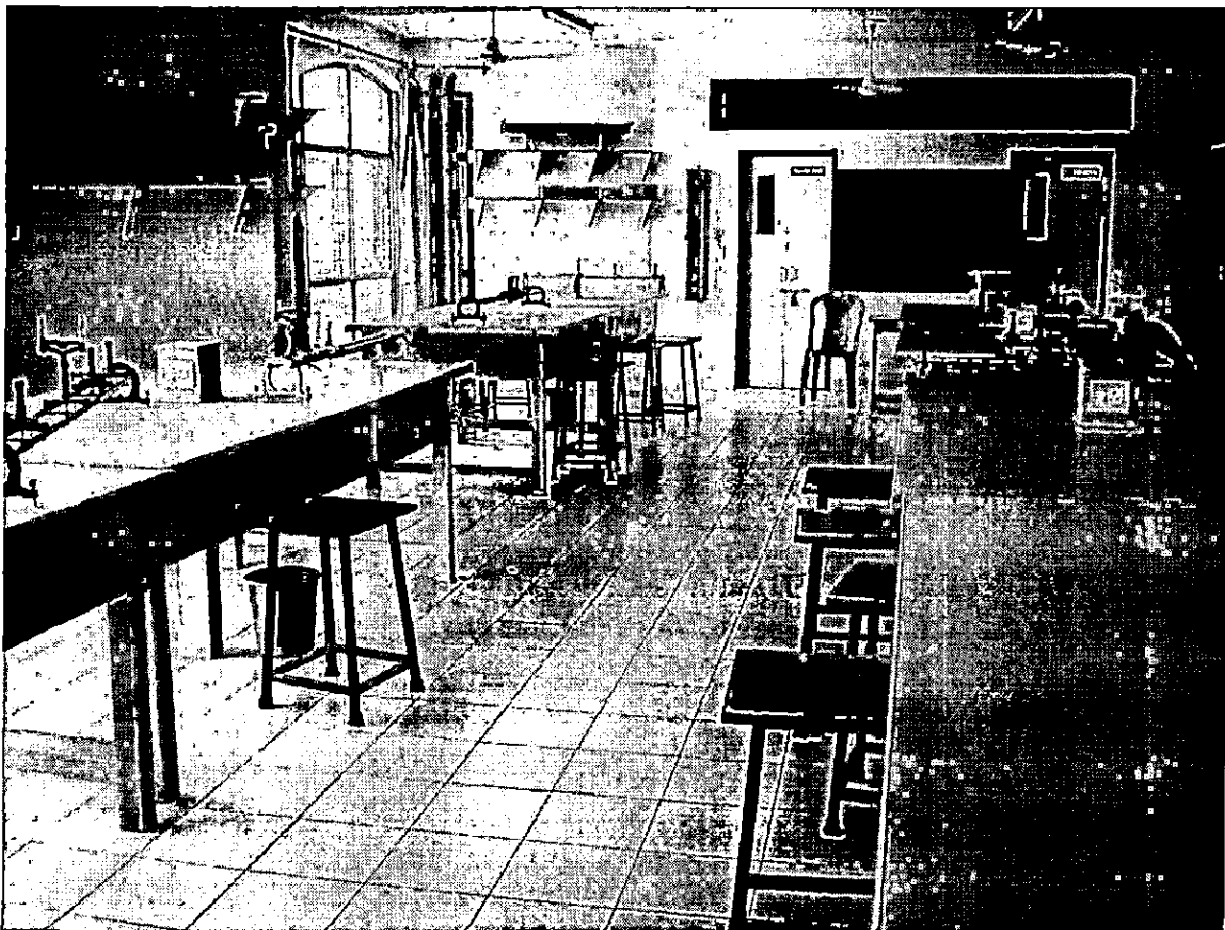
**4.2.19. EXTERIOR WALL FACADE ON WINDOW SIDES**

Window is on the North facing walls. It has been provided with a 60cm sunshade. South wall is provided with a ventilator that opens into the double side corridor. The laboratory orientation is from West to East. Light enters the room from the right side. Inner walls have been painted light matte finish pink. Window curtains have been provided. Ceilings have been painted white and floor has light cream ceramic tiles. Five luminaires have been provided. All are 40 Watt tubelights.

The illuminance levels in this space are maximum near the window sides and minimum towards the far corner. The average illuminance is within the accepted range. Artificial lighting alone doesn't provide required illuminance levels. But under normal sky conditions and in normal operating hours, it is not necessary.

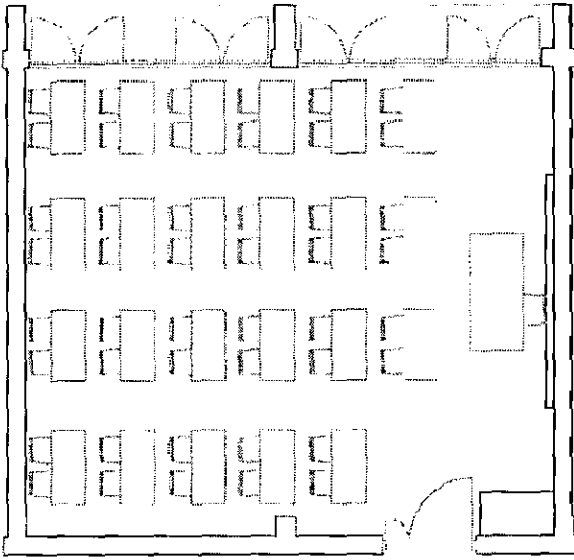
LIGHT LEVELS IN ROOMS (IN LUX)	DAYLIGHT	ARTIFICIAL LIGHT
BLACKBOARD	275	65
WINDOW CORNER	1460, 1275	115, 110
MIDDLE OF ROOM	400, 555	100, 100
FARTHEST CORNER	250, 215	90, 100
AVERAGE	601.21	92.28

TABLE 4.2.4 ILLUMINANCE LEVELS FOR TYPE 2 LABORATORY

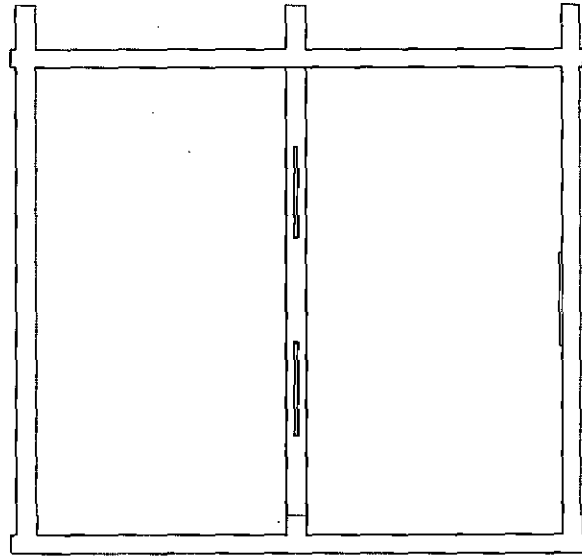


4.2.20. LABORATORY IMAGE

### 4.3 OBSERVATIONS FOR SCHOOL 3 – FATHER AGNEL SCHOOL NEW DELHI TYPE 1 CLASSROOM

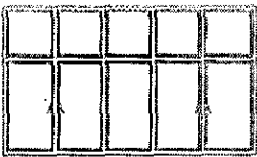


4.3.1. TYPE 1 CLASSROOM FLOOR PLAN



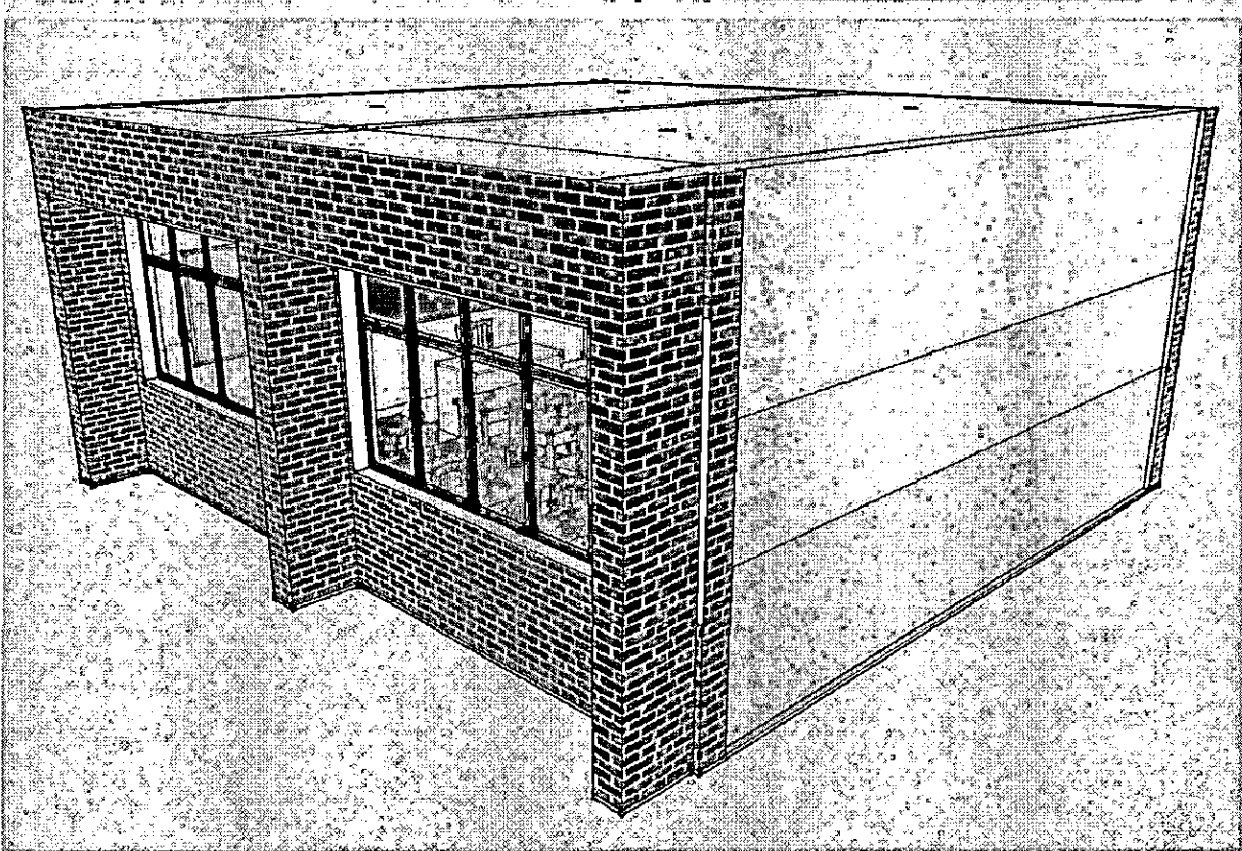
4.3.2. CEILING PLAN SHOWING FIXTURES

The floor area for Type 1 classroom is 40.5 sq.mts. Window is provided on the North West facing wall. One type of window has been provided.



Window type 1 has 90cms sill height, 275cms lintel height and Width is 310cms. Total window area is 11.76sq.mts and window to floor area ratio is 29.03%

4.3.3. TYPES OF WINDOWS USED



**4.3.4. EXTERIOR WALL FACADE ON WINDOW SIDES**

Window is on the North West facing walls. It has been recessed by 60cms. The classroom orientation is from South West to North East. Light enters the room from the left side. Inner walls have mosaic finish up to 120cms, moss green finish up to 210cms and light green above. Window curtains have been provided. Ceilings have been painted white and floor has a mosaic finish. Three luminaires have been provided. All are 40 Watt tubelights.

The illuminance levels in this space are maximum near the window sides and minimum towards the far corner. The average illuminance is within the accepted range. Artificial lighting illuminance levels are far below recommended levels but they are there only to supplement natural lighting.

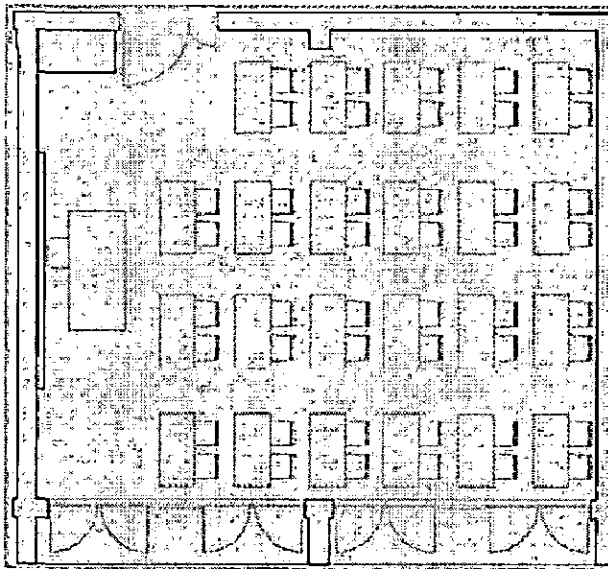
LIGHT LEVELS IN ROOMS (IN LUX)	DAYLIGHT	ARTIFICIAL LIGHT
BLACKBOARD	130	35
WINDOW CORNER	1530, 1415	55, 50
MIDDLE OF ROOM	105, 65	45, 30
FARTHEST CORNER	80, 55	35, 25
AVERAGE	458.71	37.32

TABLE 4.3.1. ILLUMINANCE LEVELS FOR TYPE 1 CLASSROOM

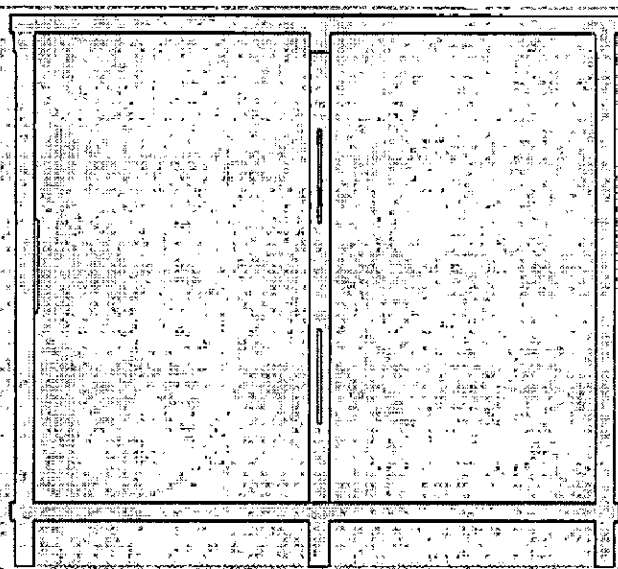


4.3.5. CLASSROOM IMAGE

**TYPE 2 CLASSROOM**



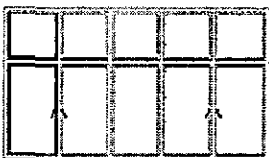
**4.3.6. TYPE 2 CLASSROOM FLOOR PLAN**



**4.3.7. CEILING PLAN SHOWING FIXTURES**

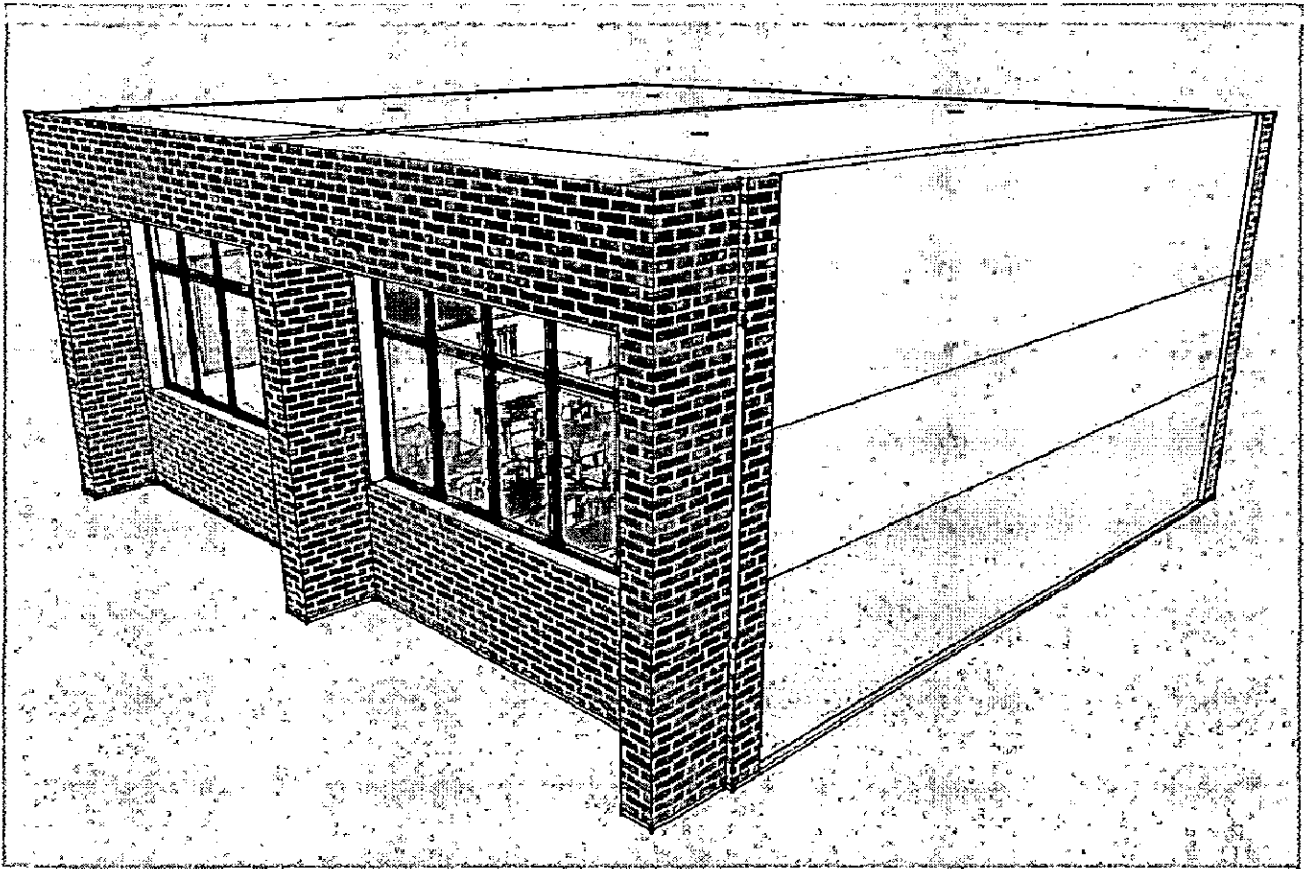
The floor area for Type 2 classroom is 40.5 sq.mts. Window is provided on the South East facing wall. One type of window has been provided.

Window type 1 has 90cms sill height, 275cms lintel height and Width is 310cms. Total window area is 11.76sq.mts and window to floor area ratio is 29.03%



**4.3.8. TYPES OF WINDOWS USED**





#### 4.3.9. EXTERIOR WALL FACADE ON WINDOW SIDES

Window is on the South East facing walls. It has been recessed by 60cms. The classroom orientation is from North East to South West. Light enters the room from the left side. Inner walls have mosaic finish up to 120cms, moss green finish up to 210cms and light green above. Window curtains have been provided. Ceilings have been painted white and floor has a mosaic finish. Three luminaires have been provided. All are 40 Watt tubelights.

The illuminance levels in this space are maximum near the window sides and minimum towards the far corner. The average illuminance is within the accepted range. Artificial lighting illuminance levels are far below recommended levels but they are there only to supplement natural lighting.

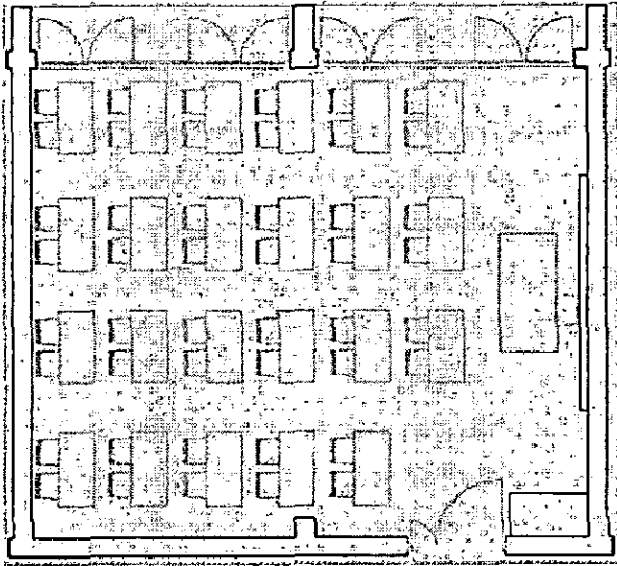
LIGHT LEVELS IN ROOMS (IN LUX)	DAYLIGHT	ARTIFICIAL LIGHT
BLACKBOARD	100	25
WINDOW CORNER	810, 760	75, 30
MIDDLE OF ROOM	140, 155	40, 25
FARTHEST CORNER	75, 60	50, 20
AVERAGE	285	35.96

TABLE 4.3.2 ILLUMINANCE LEVELS FOR TYPE 2 CLASSROOM

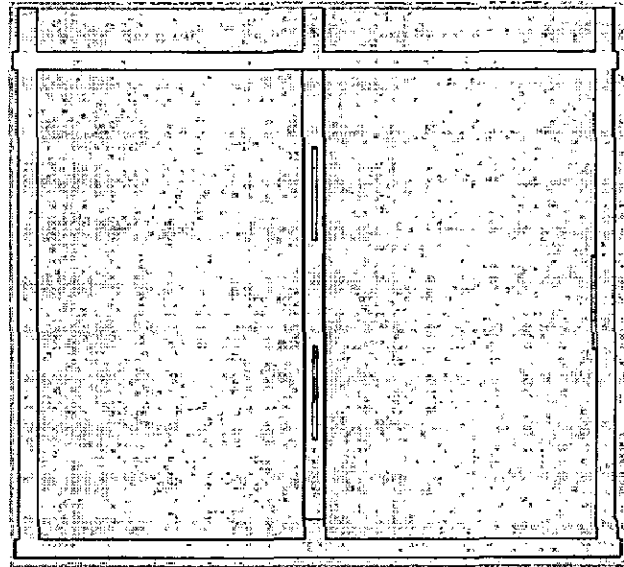


4.3.10. CLASSROOM IMAGE

**TYPE 3 CLASSROOM**



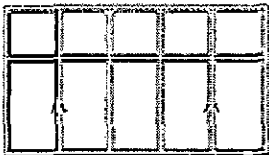
**4.3.11. TYPE 3 CLASSROOM FLOOR PLAN**



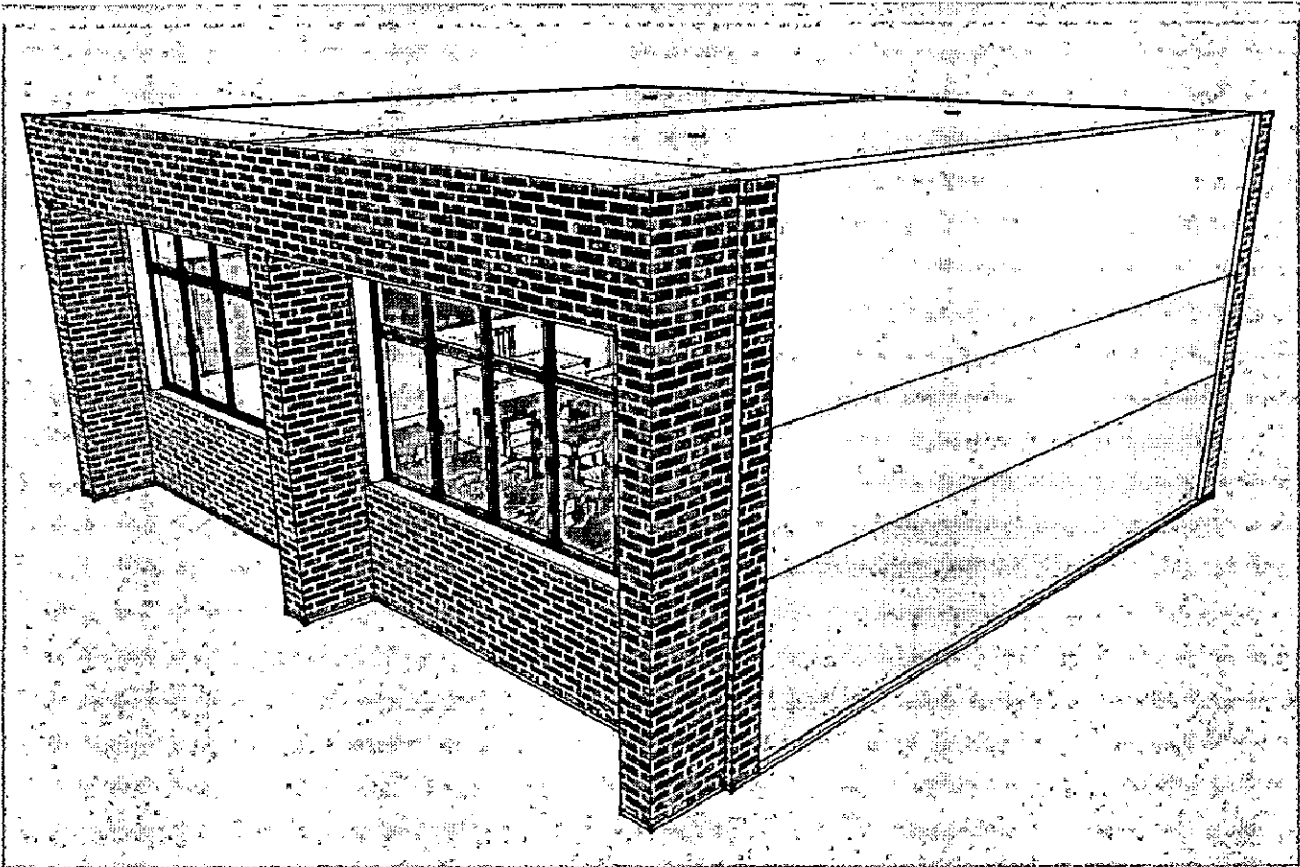
**4.3.12. CEILING PLAN SHOWING FIXTURES**

The floor area for Type 3 classroom is 40.5 sq.mts. Window is provided on the North West facing wall. One type of window has been provided.

Window type 1 has 90cms sill height, 275cms lintel height and Width is 310cms. Total window area is 11.76sq.mts and window to floor area ratio is 29.03%



**4.3.13. TYPES OF WINDOWS USED**



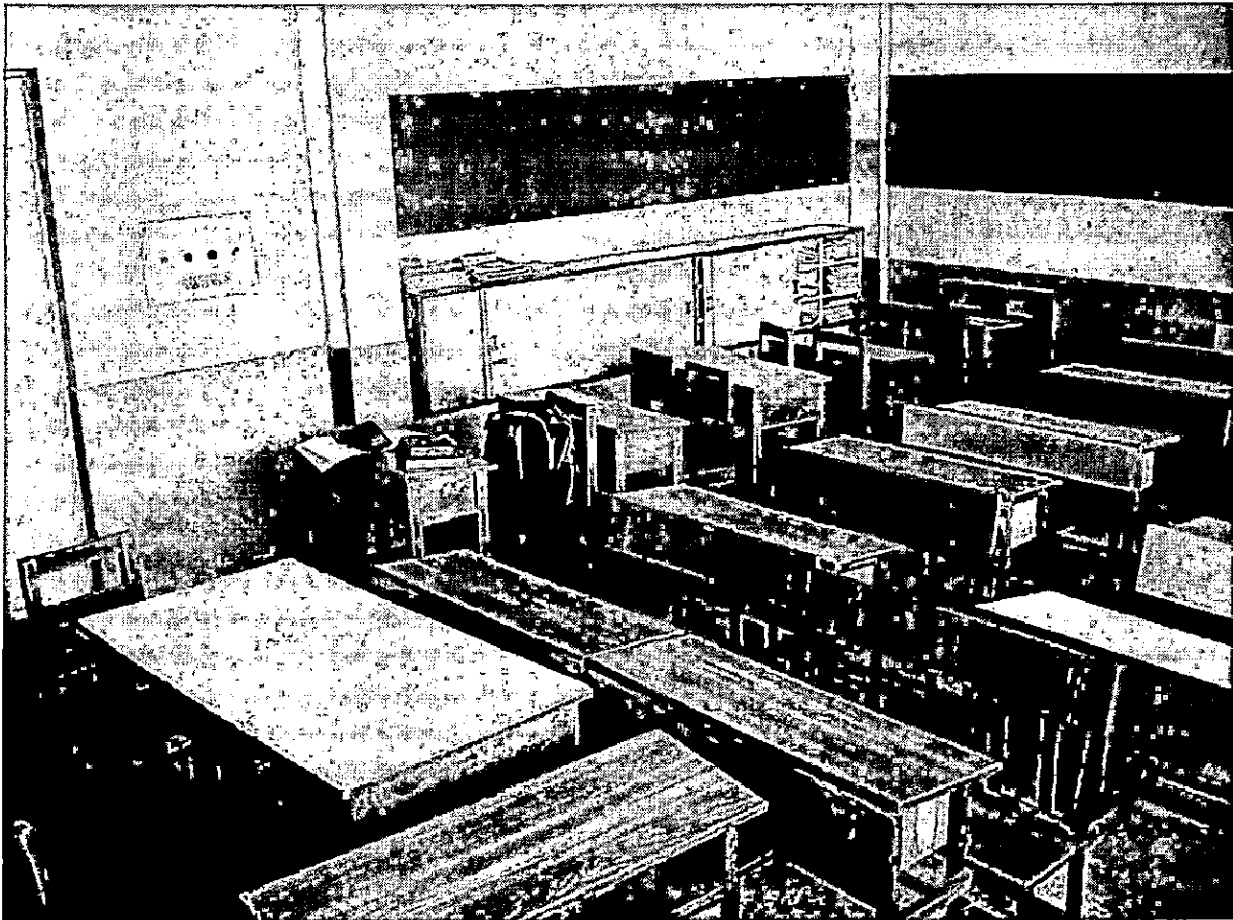
**4.3.14. EXTERIOR WALL FACADE ON WINDOW SIDES**

Window is on the North West facing walls. It has been recessed by 60cms. The classroom orientation is from South West to North East. Light enters the room from the left side. Inner walls have mosaic finish up to 120cms, moss green finish up to 210cms and light green above. Window curtains have been provided. Ceilings have been painted white and floor has a mosaic finish. Three luminaires have been provided. All are 40 Watt tubelights.

The illuminance levels in this space are maximum near the window sides and minimum towards the far corner. The average illuminance is within the accepted range. Artificial lighting illuminance levels are far below recommended levels but they are there only to supplement natural lighting.

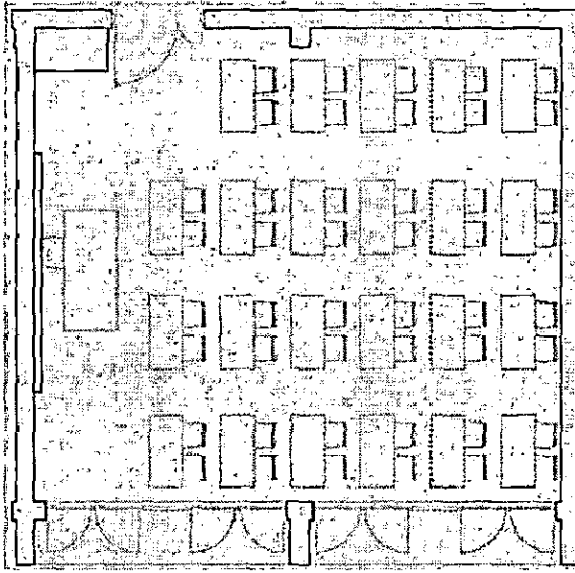
LIGHT LEVELS IN ROOMS (IN LUX)	DAYLIGHT	ARTIFICIAL LIGHT
BLACKBOARD	345	40
WINDOW CORNER	2230, 2205	50, 75
MIDDLE OF ROOM	300, 225	50, 40
FARTHEST CORNER	590, 470	50, 30
AVERAGE	863.82	45.46

TABLE 4.3.3 ILLUMINANCE LEVELS FOR TYPE 3 CLASSROOM

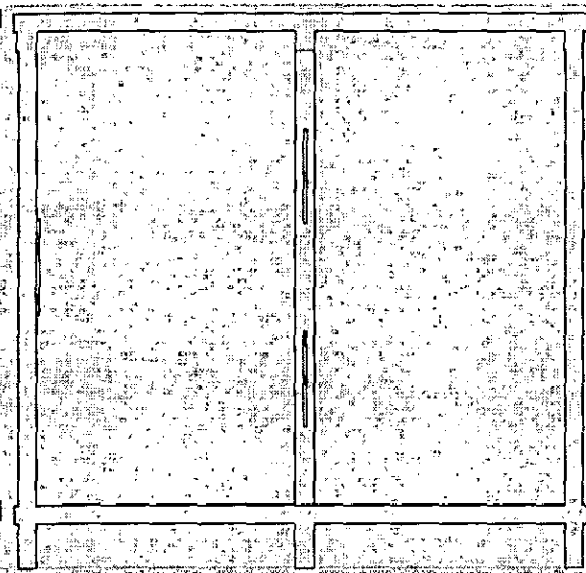


4.3.15. CLASSROOM IMAGE

**TYPE 4 CLASSROOM**



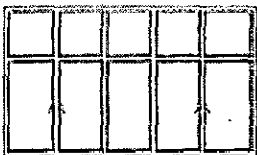
**4.3.16. TYPE 4 CLASSROOM FLOOR PLAN**



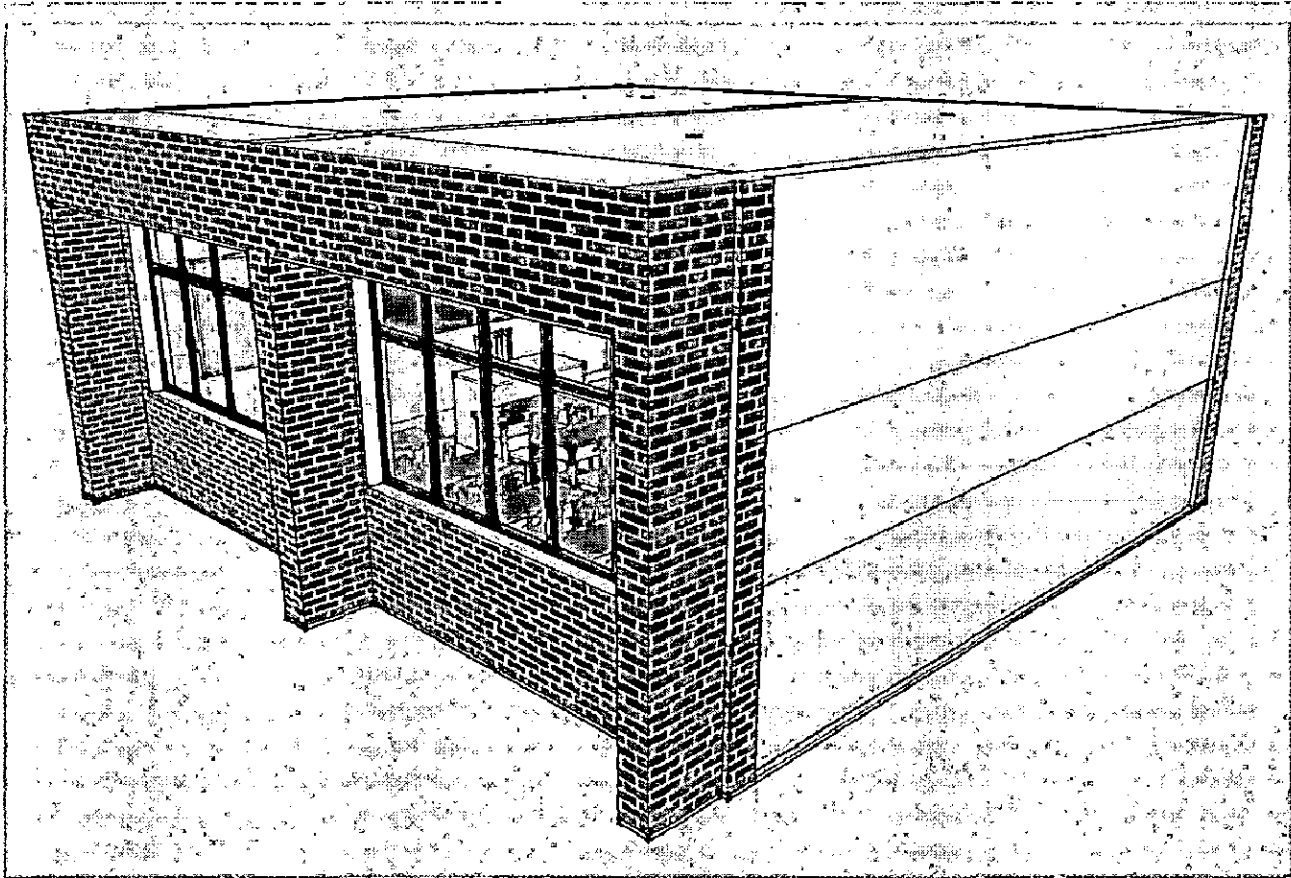
**4.3.17. CEILING PLAN SHOWING FIXTURES**

The floor area for Type 4 classroom is 40.5sq.mts. Window is provided on the South East facing wall. One type of window has been provided.

Window type 1 has 90cms sill height, 275cms lintel height and Width is 310cms. Total window area is 11.76sq.mts and window to floor area ratio is 29.03%



**4.3.18. TYPES OF WINDOWS USED**



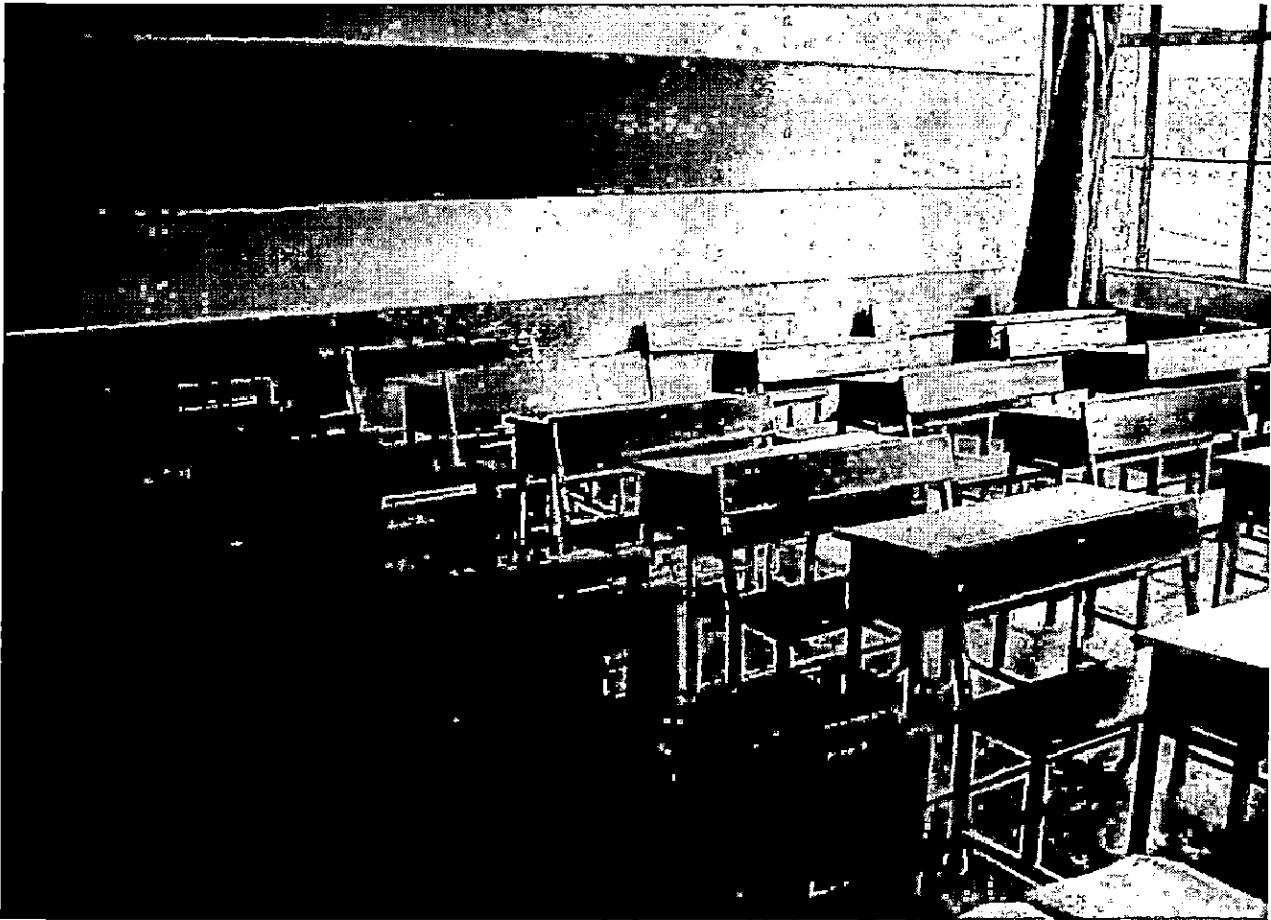
**4.3.19. EXTERIOR WALL FACADE ON WINDOW SIDES**

Window is on the South East facing walls. It has been recessed by 60cms. The classroom orientation is from North East to South West. Light enters the room from the left side. Inner walls have mosaic finish up to 120cms, moss green finish up to 210cms and light green above. Window curtains have been provided. Ceilings have been painted white and floor has a mosaic finish. Three luminaires have been provided. All are 40 Watt tubelights.

The illuminance levels in this space are maximum near the window sides and minimum towards the far corner. The average illuminance is within the accepted range. Artificial lighting illuminance levels are far below recommended levels but they are there only to supplement natural lighting.

LIGHT LEVELS IN ROOMS (IN LUX)	DAYLIGHT	ARTIFICIAL LIGHT
BLACKBOARD	425	45
WINDOW CORNER	2880, 2645	70, 115
MIDDLE OF ROOM	640, 525	45, 50
FARTHEST CORNER	190, 160	50, 30
AVERAGE	1013.10	54.96

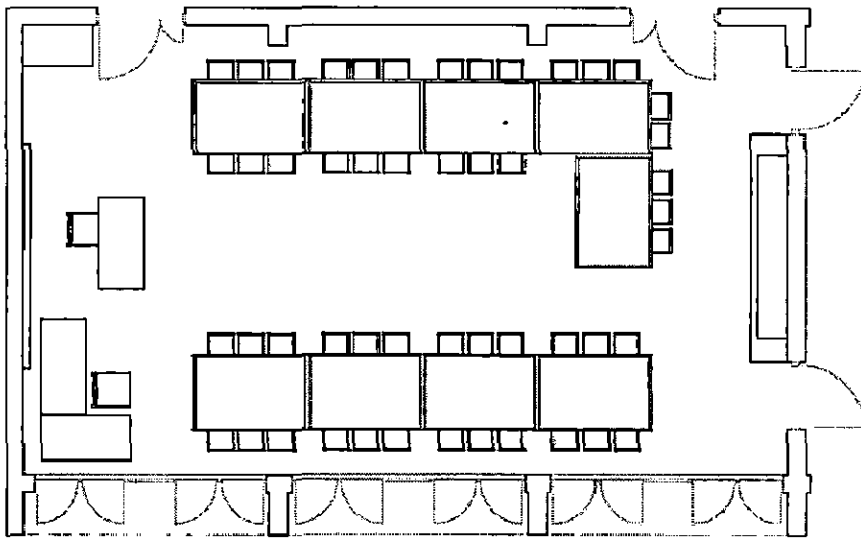
TABLE 4.3.4. ILLUMINANCE LEVELS FOR TYPE 4 CLASSROOM



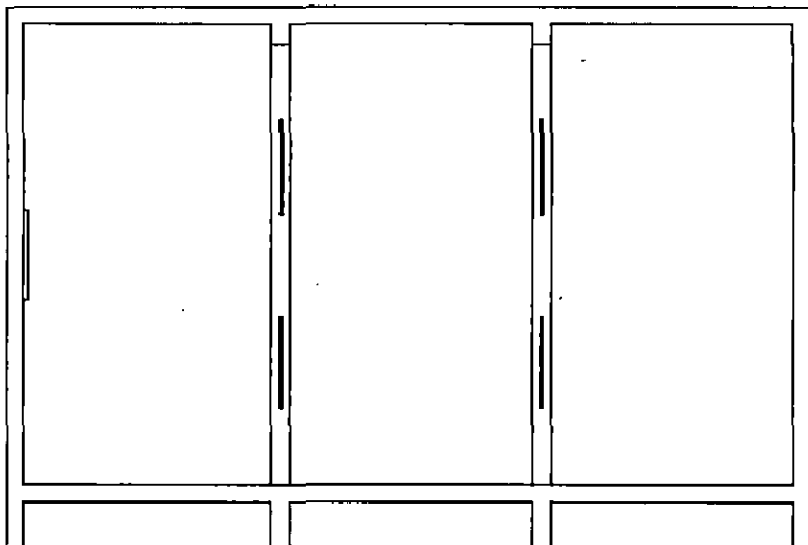
4.3.20. CLASSROOM IMAGE



**TYPE 1 LABORATORY**

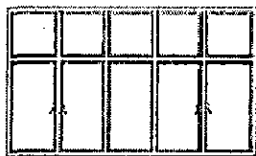


**4.3.21. TYPE 1 LABORATORY FLOOR PLAN**



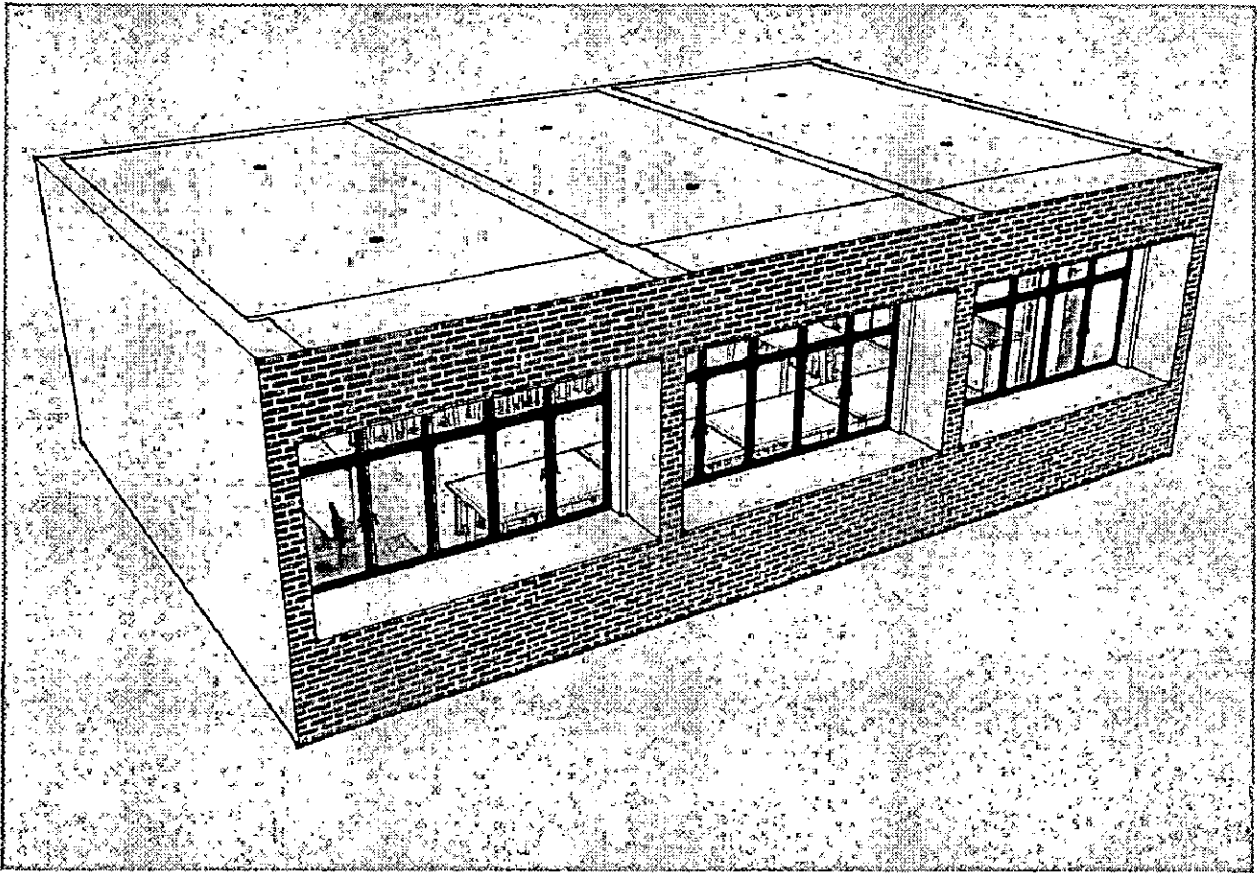
**4.3.22. CEILING PLAN SHOWING FIXTURES**

The floor area for Type 1 laboratory is 61.2 sq.mts. Window is provided on the South East facing wall. One type of window has been provided.



Window type 1 has 90cms sill height, 275cms lintel height and Width is 310cms. Total window area is 17.64sq.mts and window to floor area ratio is 28.82%

**4.3.23. TYPES OF WINDOWS USED**



**4.3.24. EXTERIOR WALL FACADE ON WINDOW SIDES**

Window is on the South East facing walls. It has been recessed by 60cms. The classroom orientation is from South East to North West. Light enters the room from the left side. Inner walls are painted white. Window curtains have been provided. Ceilings have been painted white and floor has a mosaic finish. Five luminaires have been provided. All are 40 Watt tubelights.

The illuminance levels in this space are maximum near the window sides and minimum towards the far corner. The average illuminance is above the accepted range. Artificial lighting illuminance levels are far below recommended levels but they are there only to supplement natural lighting and are not required in normal conditions.

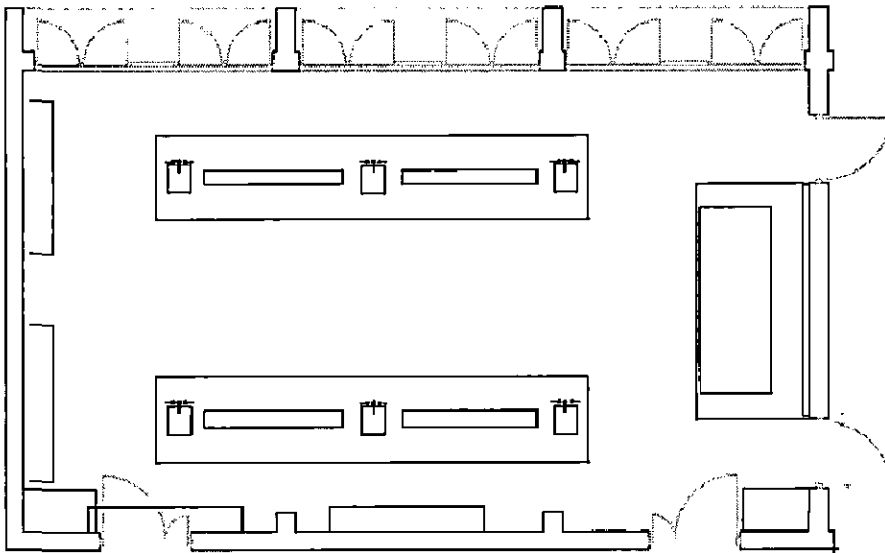
LIGHT LEVELS IN ROOMS (IN LUX)	DAYLIGHT	ARTIFICIAL LIGHT
BLACKBOARD	450	75
WINDOW CORNER	2250, 2570	80, 90
MIDDLE OF ROOM	780, 900	70, 85
FARTHEST CORNER	455, 445	70, 40
AVERAGE	1065.35	69.21

TABLE 4.3.5. ILLUMINANCE LEVELS FOR TYPE 1 LABORATORY

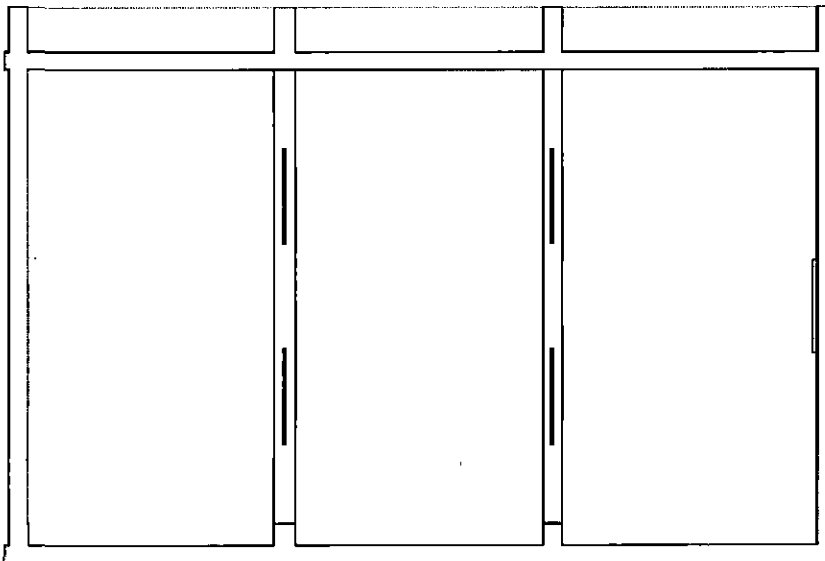


4.3.25. LABORATORY IMAGE

**TYPE 2 LABORATORY**



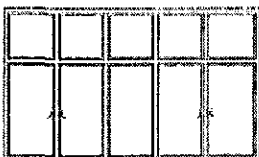
**4.3.26. TYPE 2 LABORATORY FLOOR PLAN**



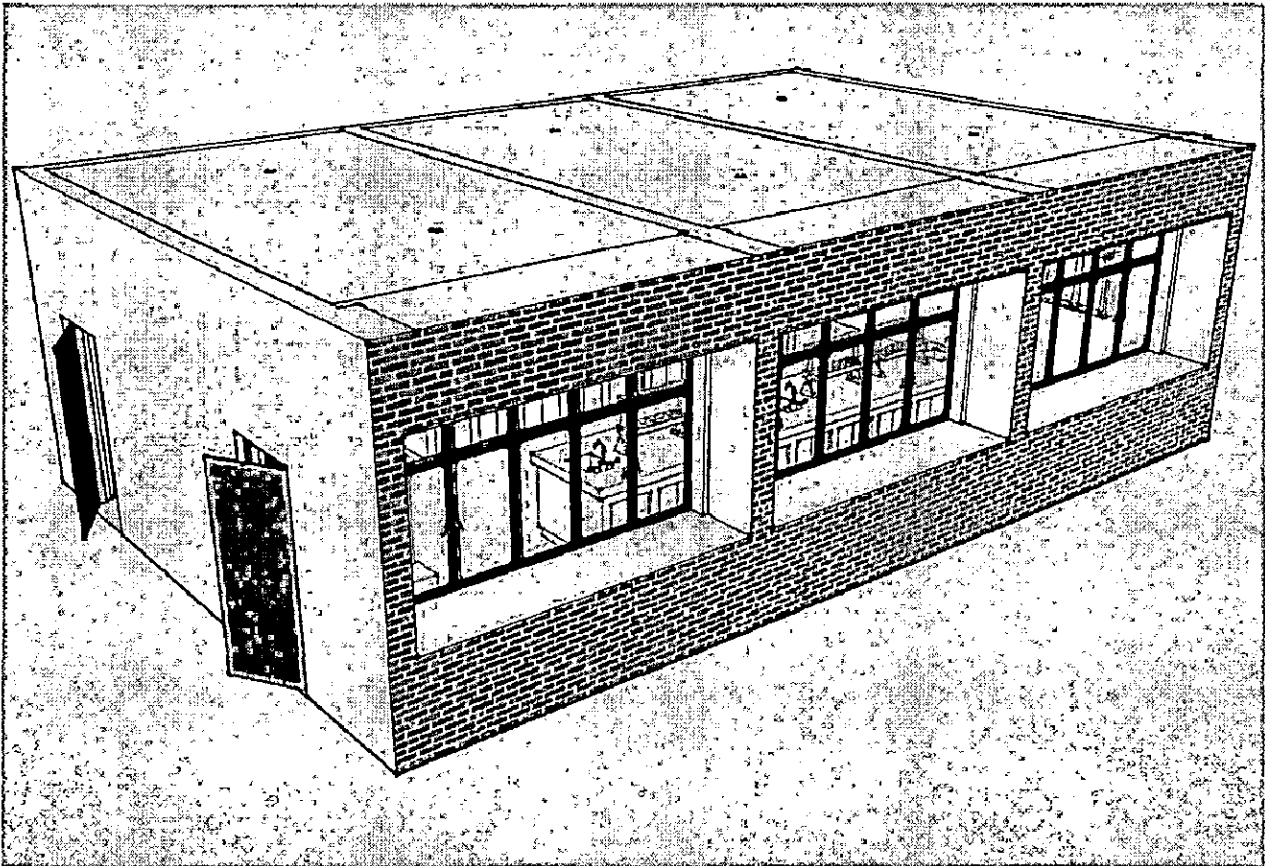
**4.3.27. CEILING PLAN SHOWING FIXTURES**

The floor area for Type 2 laboratory is 61.2 sq.mts. Window is provided on the North West facing wall. One type of window has been provided.

Window type 1 has 90cms sill height, 275cms lintel height and Width is 310cms. Total window area is 17.64sq.mts and window to floor area ratio is 28.82%



**4.3.28 TYPES OF WINDOWS USED**



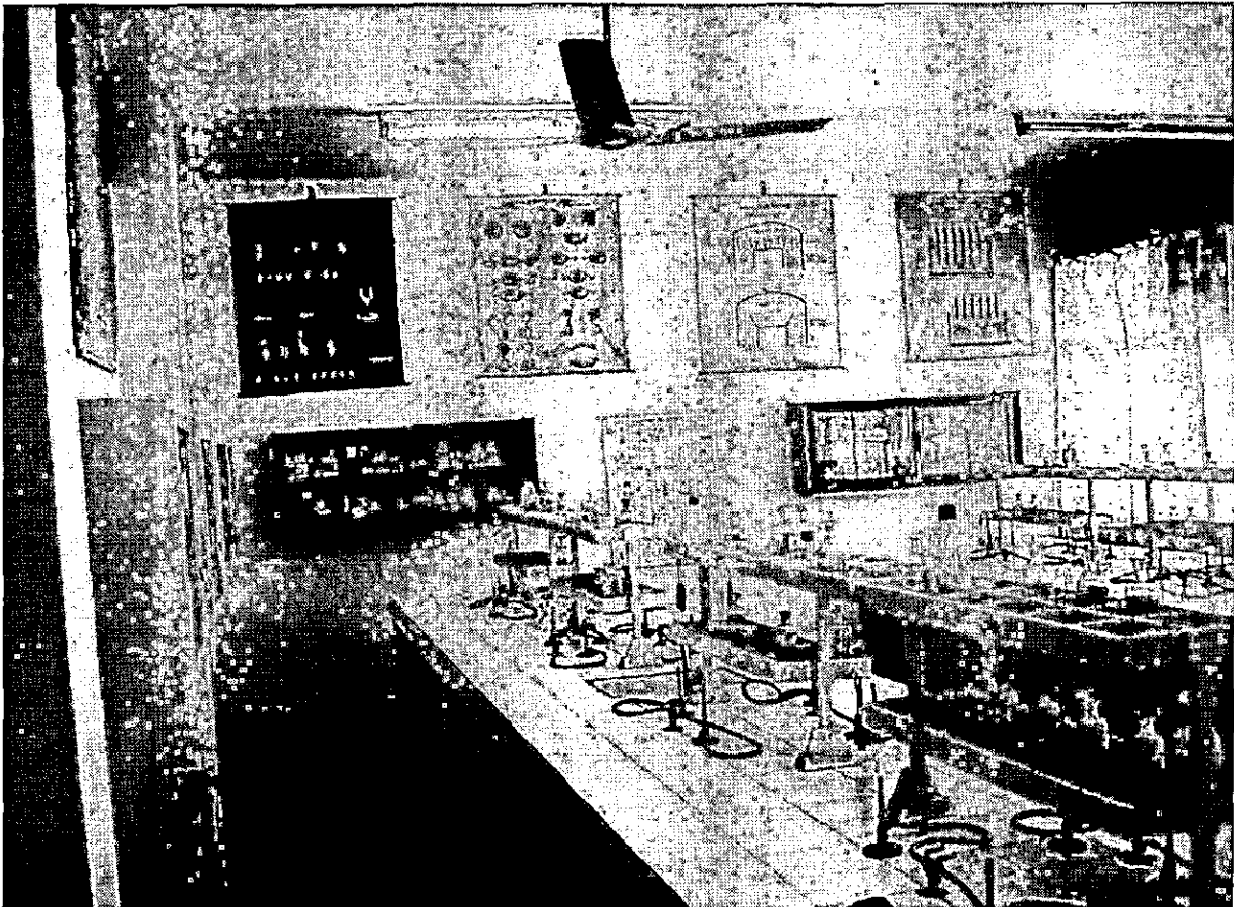
**4.3.29. EXTERIOR WALL FACADE ON WINDOW SIDES**

Window is on the North West facing walls. It has been recessed by 60cms. The classroom orientation is from North East to South West. Light enters the room from the left side. Inner walls are painted white. Window curtains have been provided. Ceilings have been painted white and floor has a mosaic finish. Five luminaires have been provided. All are 40 Watt tubelights.

The illuminance levels in this space are maximum near the window sides and minimum towards the far corner. The average illuminance is within the accepted range. Artificial lighting illuminance levels are far below recommended levels but they are there only to supplement natural lighting and are not required in normal conditions.

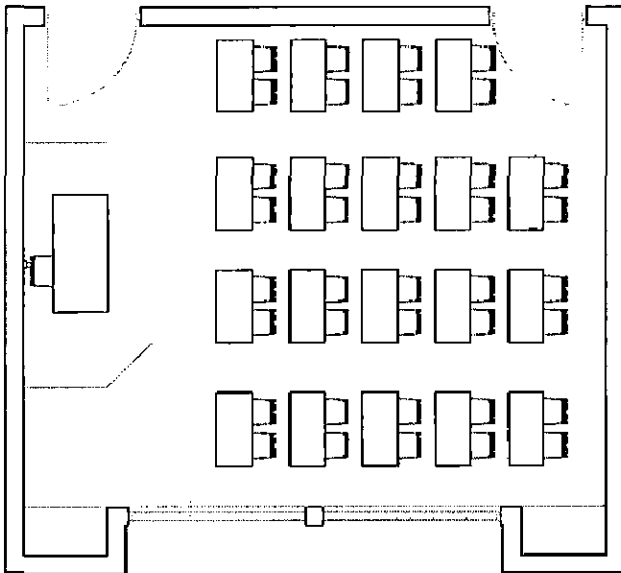
LIGHT LEVELS IN ROOMS (IN LUX)	DAYLIGHT	ARTIFICIAL LIGHT
BLACKBOARD	345	130
WINDOW CORNER	1430, 1460	140, 90
MIDDLE OF ROOM	300, 380	125, 65
FARTHEST CORNER	250, 230	100, 55
AVERAGE	596.46	95.68

TABLE 4.3.6. ILLUMINANCE LEVELS FOR TYPE 1 LABORATORY

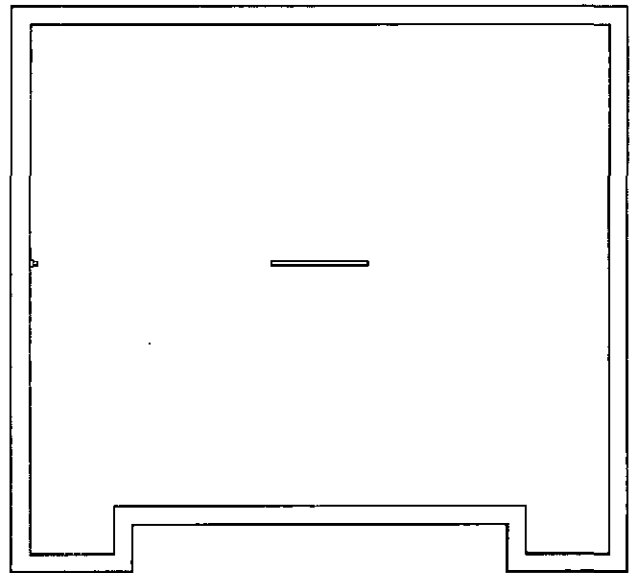


4.3.30. LABORATORY IMAGE

**4.4 OBSERVATIONS FOR SCHOOL 4 – KERALA SCHOOL NEW DELHI  
TYPE 1 CLASSROOM**

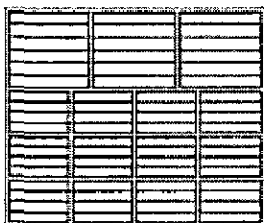


4.4.1. TYPE 1 CLASSROOM FLOOR PLAN



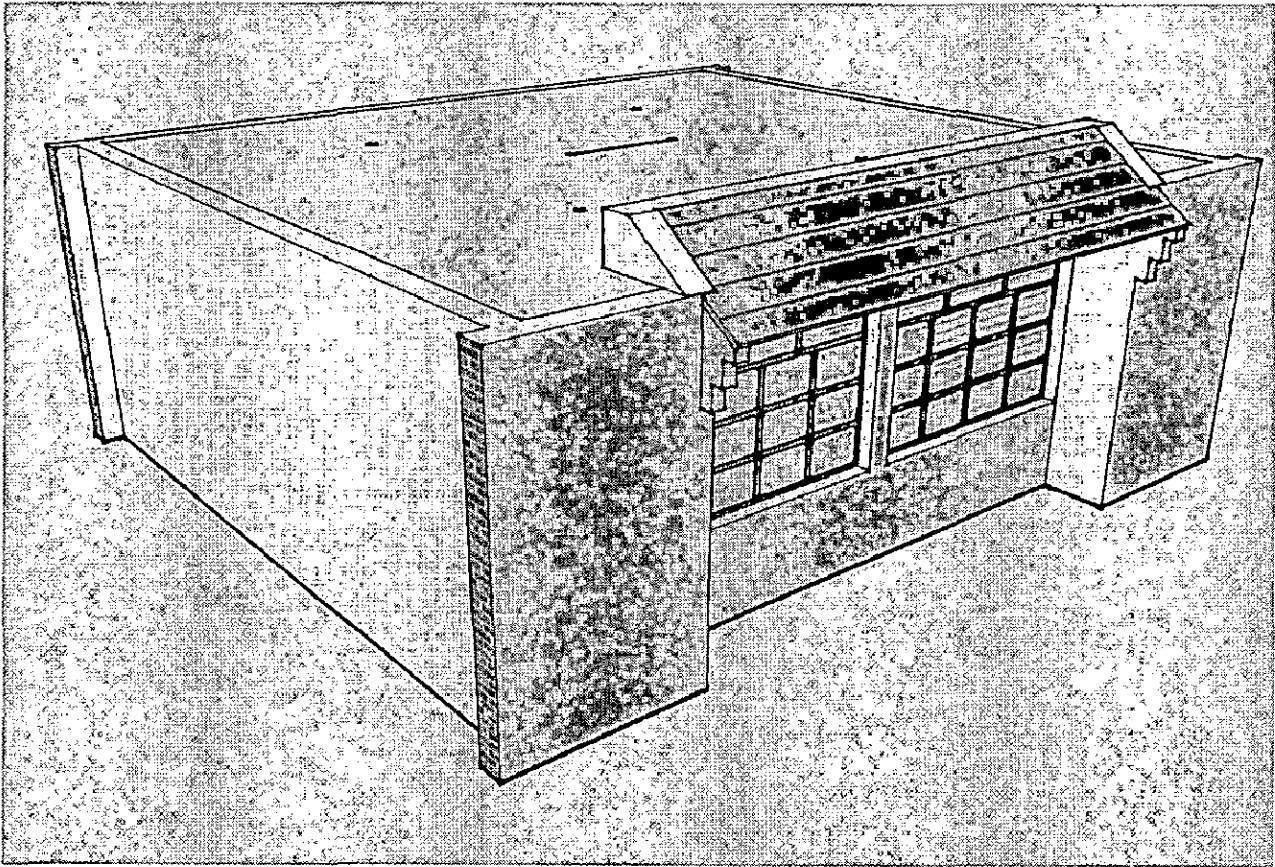
4.4.2. CEILING PLAN SHOWING FIXTURES

The floor area for Type 1 classroom is 43.9 sq.mts. Window is provided on the South East facing wall. One type of window has been provided.



Window type 1 has 85cms sill height, 270cms lintel height and Width is 220cms. Total window area is 9.58sq.mts and window to floor area ratio is 21.82%

4.4.3. TYPE OF WINDOW USED



#### 4.4.4. EXTERIOR WALL FACADE ON WINDOW SIDES

Window is on the South East facing wall. It has been recessed by 60cms and has a sloping sunshade designed to mimic traditional Kerala architecture. The classroom orientation is from North East to South West. Light enters the room from the left side. Inner walls are painted white. No window curtains have been provided. Ceilings have been painted white and floor has a mosaic finish. Two luminaires have been provided. Both are 40 Watt tubelights.

The illuminance levels in this space are maximum near the window sides and minimum towards the far corner. The average illuminance is within the accepted range. Artificial lighting does not significantly affect room illuminance levels.



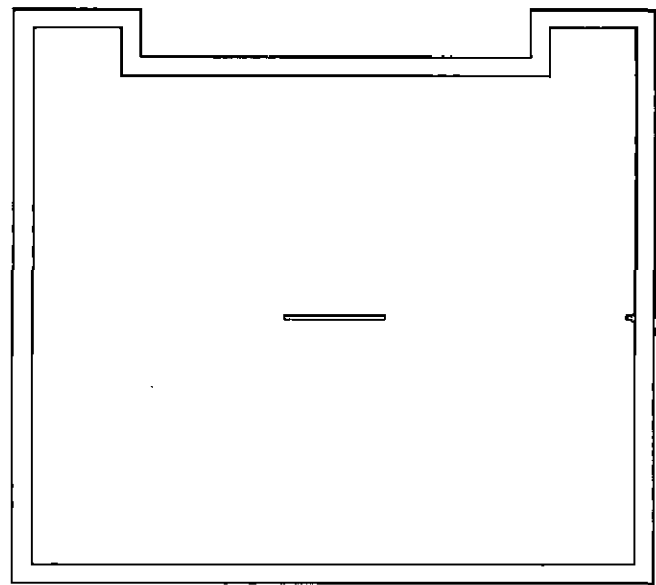
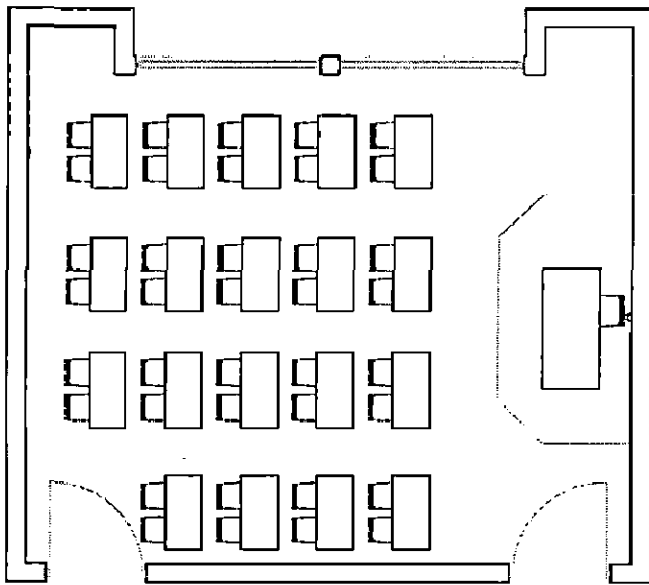
LIGHT LEVELS IN ROOMS (IN LUX)	DAYLIGHT	ARTIFICIAL LIGHT
BLACKBOARD	360	1315
WINDOW CORNER	1205, 955	1210, 970
MIDDLE OF ROOM	650, 465	660, 475
FARTHEST CORNER	345, 225	355, 230
AVERAGE	570.67	707.75

TABLE 4.4.1. ILLUMINANCE LEVELS FOR TYPE 1 CLASSROOM



4.4.5. CLASSROOM IMAGE

**TYPE 2 CLASSROOM**

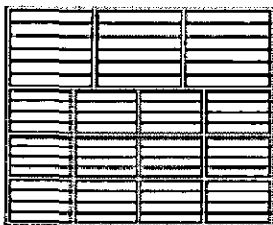


**4.4.6. TYPE 2 CLASSROOM FLOOR PLAN**

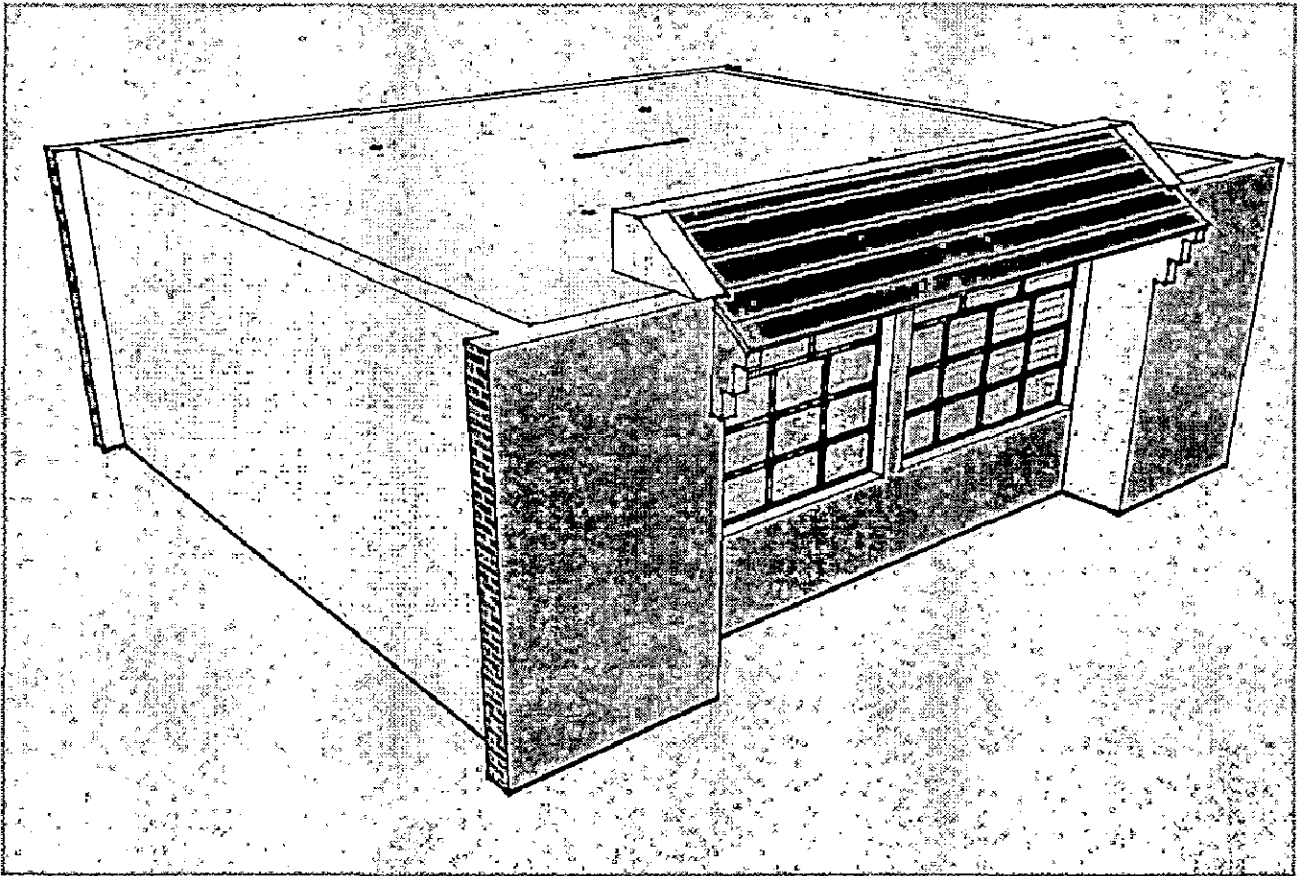
**4.4.7. CEILING PLAN SHOWING FIXTURES**

The floor area for Type 2 classroom is 43.9 sq.mts. Window is provided on the North West facing wall. One type of window has been provided.

Window type 1 has 85cms sill height, 270cms lintel height and Width is 220cms. Total window area is 9.58sq.mts and window to floor area ratio is 21.82%



**4.4.8. TYPE OF WINDOW USED**



**4.4.9. EXTERIOR WALL FACADE ON WINDOW SIDES**

Window is on the North West facing wall. It has been recessed by 60cms and has a sloping sunshade designed to mimic traditional Kerala architecture. The classroom orientation is from South West to North East. Light enters the room from the left side. Inner walls are painted white. No window curtains have been provided. Ceilings have been painted white and floor has been tiled in white, making it appear visually larger than type 1 classroom. Two luminaires have been provided. Both are 40 Watt tubelights.

The illuminance levels in this space are maximum near the window sides and minimum towards the far corner. The average illuminance is within the accepted range. Artificial lighting does not significantly affect room illuminance levels.

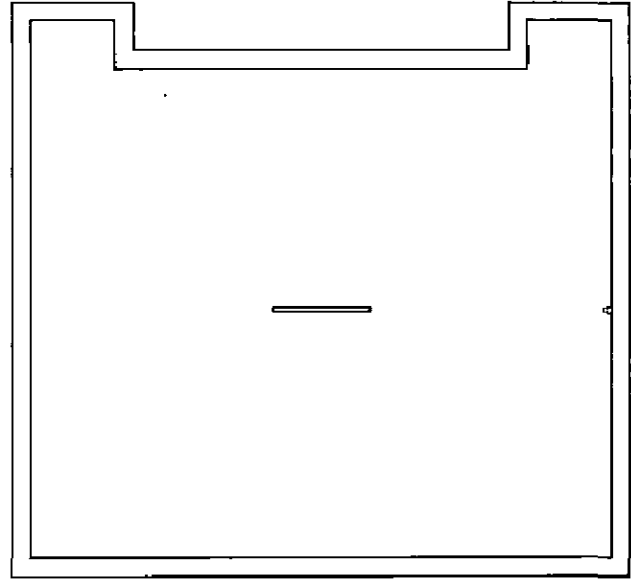
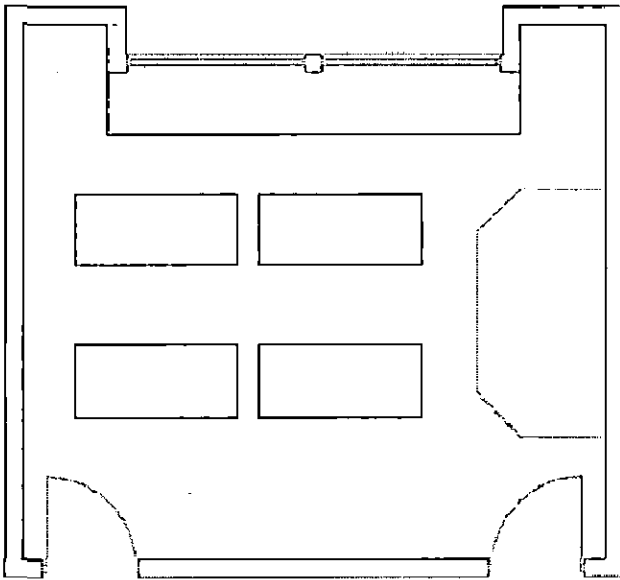
LIGHT LEVELS IN ROOMS (IN LUX)	DAYLIGHT	ARTIFICIAL LIGHT
BLACKBOARD	200	860
WINDOW CORNER	1345, 230	1365, 255
MIDDLE OF ROOM	440, 175	480, 195
FARTHEST CORNER	380, 125	410, 135
AVERAGE	392.89	502.14

TABLE 4.4.2. ILLUMINANCE LEVELS FOR TYPE 2 CLASSROOM



4.4.10. CLASSROOM IMAGE

**TYPE 1 LABORATORY**

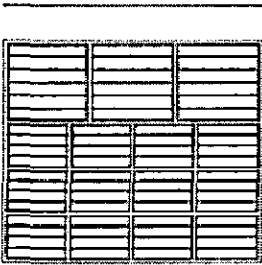


**4.4.11. TYPE 1 LABORATORY FLOOR PLAN**

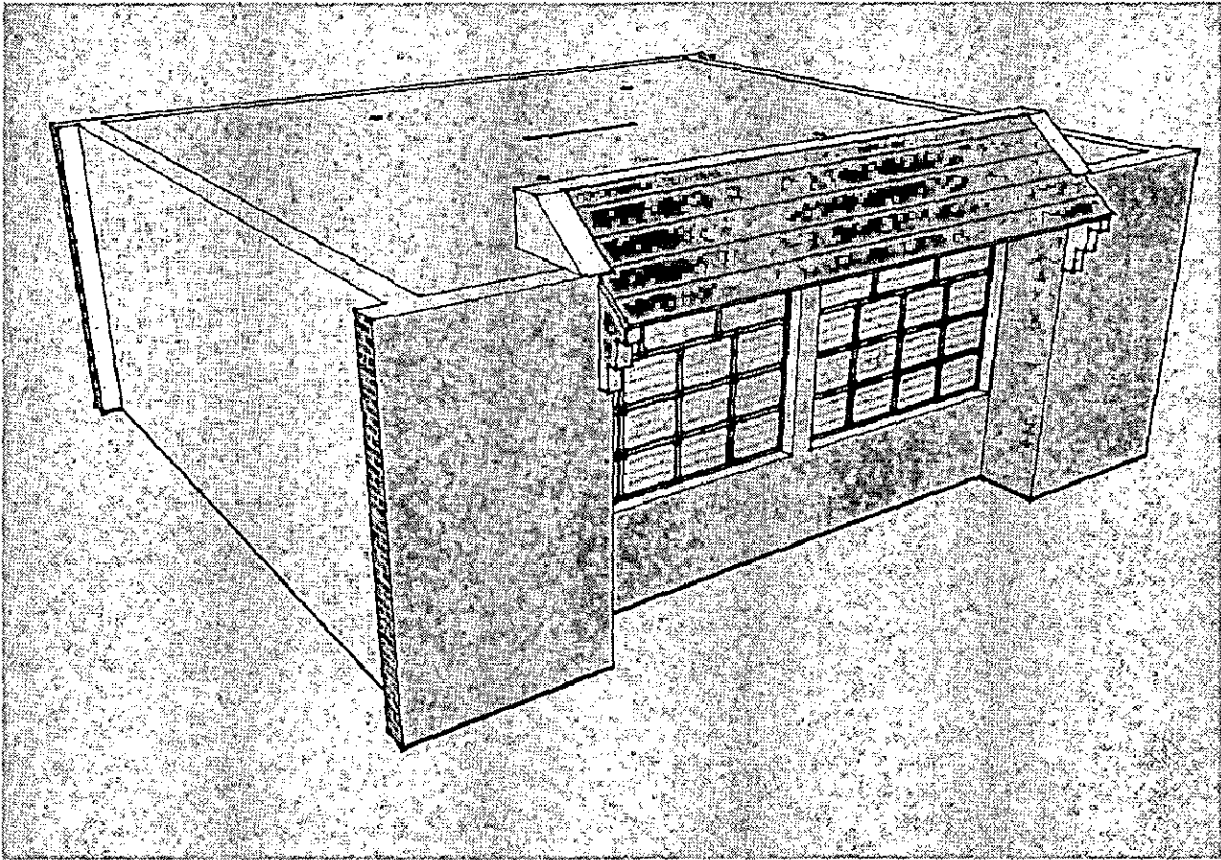
**4.4.12. CEILING PLAN SHOWING FIXTURES**

The floor area for Type 1 laboratory is 43.9 sq.mts. Window is provided on the North West facing wall. One type of window has been provided.

Window type 1 has 85cms sill height, 270cms lintel height and Width is 220cms. Total window area is 9.58sq.mts and window to floor area ratio is 21.82%



**4.4.13. TYPE OF WINDOW USED**



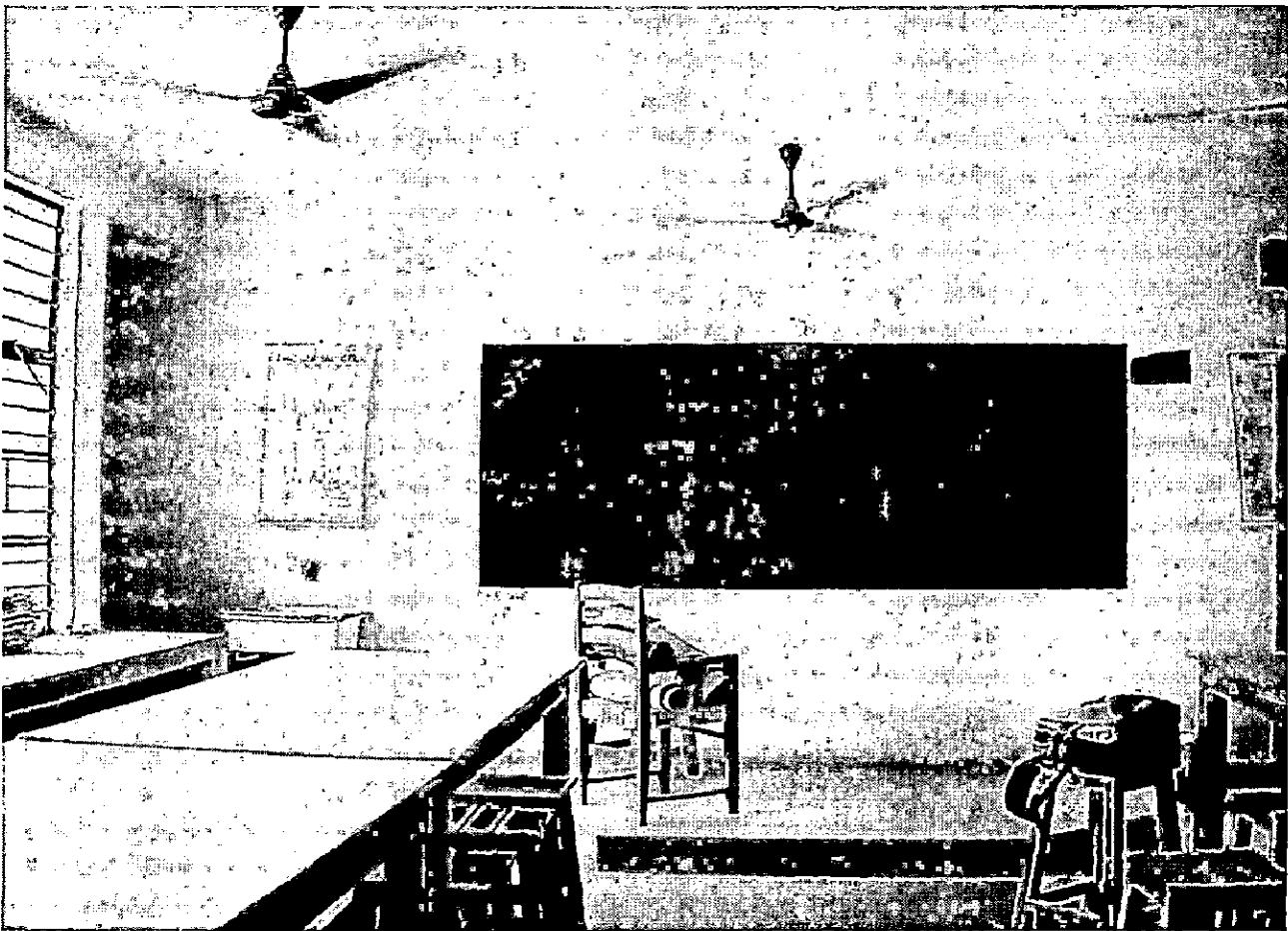
**4.4.14. EXTERIOR WALL FACADE ON WINDOW SIDES**

Window is on the North West facing wall. It has been recessed by 60cms and has a sloping sunshade designed to mimic traditional Kerala architecture. The classroom orientation is from South West to North East. Light enters the room from the left side. Inner walls are painted white. No window curtains have been provided. Ceilings have been painted white and floor has been given mosaic finish. Two luminaires have been provided. Both are 40 Watt tubelights.

The illuminance levels in this space are maximum near the window sides and minimum towards the far corner. The average illuminance is within the accepted range. Artificial lighting does not significantly affect room illuminance levels.

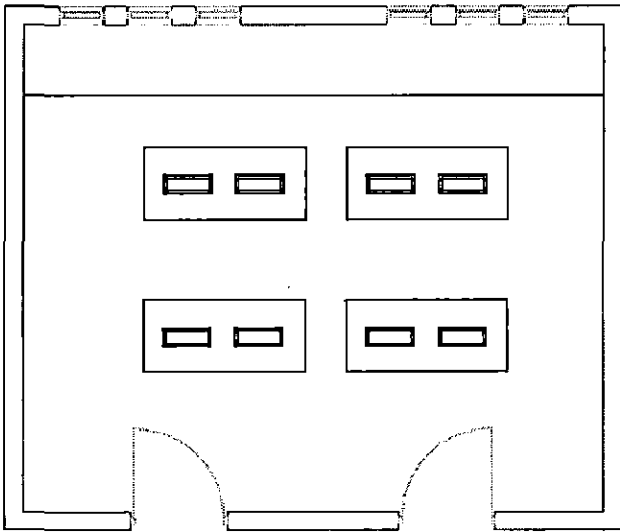
LIGHT LEVELS IN ROOMS (IN LUX)	DAYLIGHT	ARTIFICIAL LIGHT
BLACKBOARD	210	770
WINDOW CORNER	1380, 1290	1430, 1310
MIDDLE OF ROOM	445, 355	485, 385
FARTHEST CORNER	170, 145	185, 165
AVERAGE	542.17	641.93

TABLE 4.4.3. ILLUMINANCE LEVELS FOR TYPE 1 LABORATORY

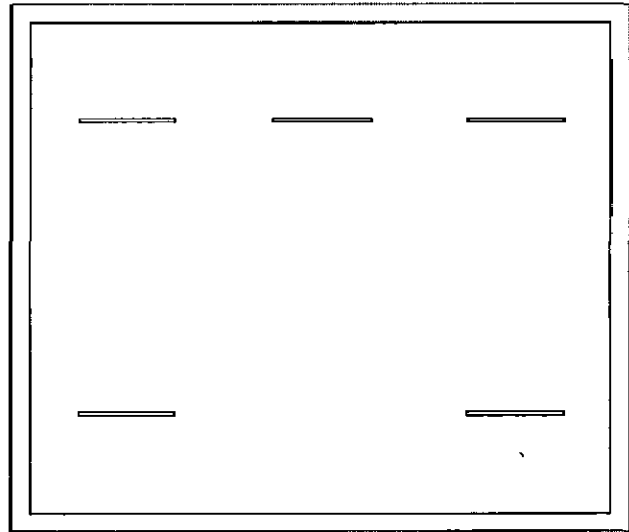


4.4.15. LABORATORY IMAGE

**TYPE 2 LABORATORY**



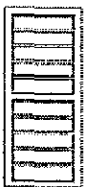
**4.4.16. TYPE 2 LABORATORY FLOOR PLAN**



**4.4.17. CEILING PLAN SHOWING FIXTURES**

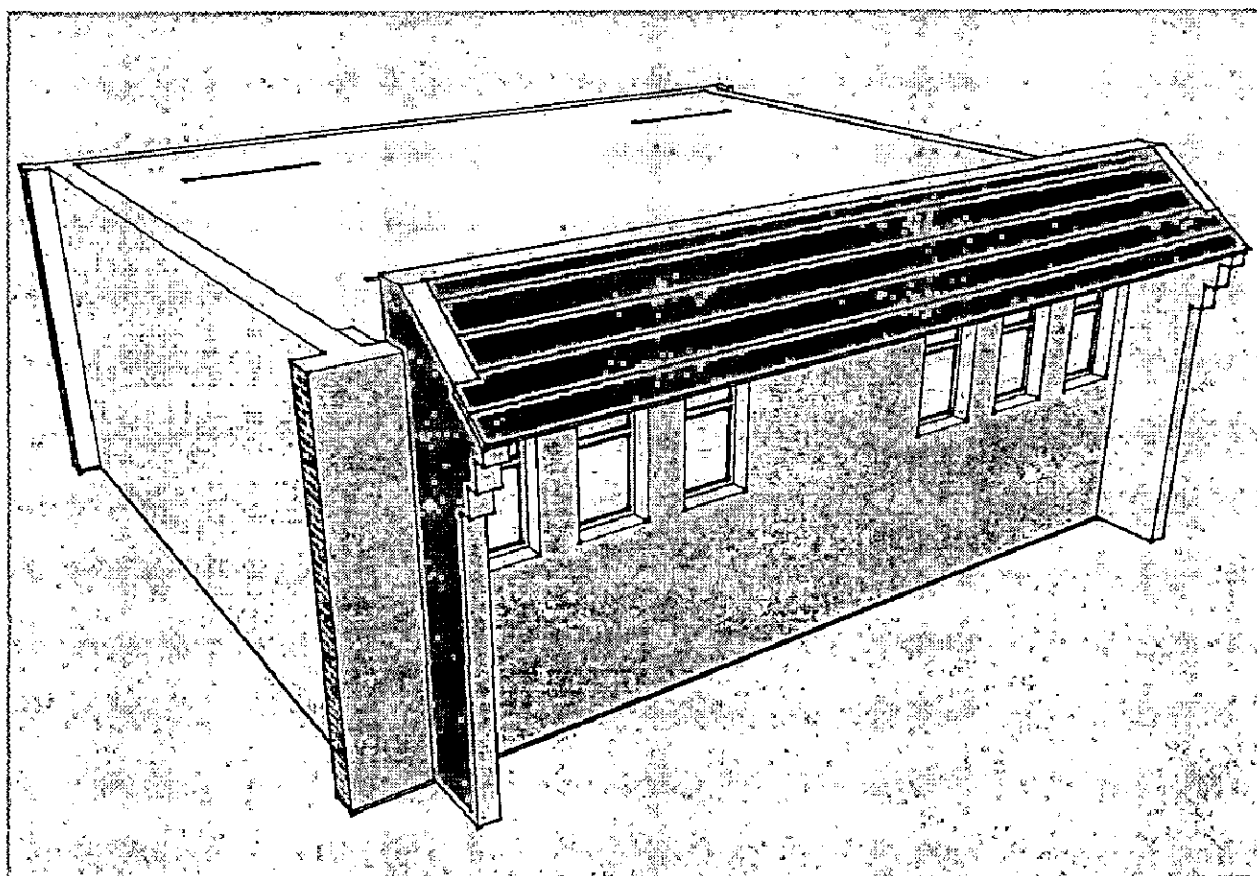
The floor area for Type 2 laboratory is 43.9 sq.mts. Window is provided on the North West facing wall. One type of window has been provided.

Window type 2 has 140cms sill height, 270cms lintel height and Width is 55cms. Total window area is 5.73sq.mts and window to floor area ratio is 13.05%



**4.4.18. TYPE OF WINDOW USED**





**4.4.19. EXTERIOR WALL FACADE ON WINDOW SIDES**

Window is on the North West facing wall. It has been recessed by 60cms and has a sloping sunshade designed to mimic traditional Kerala architecture. The classroom orientation is from North East to South West. Light enters the room from the right side. Inner walls are painted white. No window curtains have been provided. Ceilings have been painted white and floor has been tiled in white ceramic tiles. Five luminaires have been provided. All are 40 Watt tubelights.

The illuminance levels in this space are maximum near the window sides and minimum towards the far corner. The average illuminance is far below the accepted range. Artificial lighting significantly affects room illuminance levels however it is still not sufficient enough to be considered well lit. To lessen the impact of minimal lighting, the floor tiles are white and they make the room appear slightly larger.

LIGHT LEVELS IN ROOMS (IN LUX)	DAYLIGHT	ARTIFICIAL LIGHT
BLACKBOARD	55	95
WINDOW CORNER	140, 125	230, 130
MIDDLE OF ROOM	90, 55	155, 100
FARTHEST CORNER	40, 25	70, 40
AVERAGE	71.93	111.28

TABLE 4.4.4. ILLUMINANCE LEVELS FOR TYPE 2 LABORATORY



4.4.20. LABORATORY IMAGE

**4.5 SPATIAL DIMENSIONS (IN MTS)**

SPATIAL DIMENSIONS (LxBxH)	SCHOOL 1	SCHOOL 2	SCHOOL 3	SCHOOL 4
CLASSROOM 1	7.40 x 6.00 x 3.15	7.40 x 6.60 x 3.10	6.75 x 6.00 x 3.35	7.20 x 6.10 x 3.00
CLASSROOM 2	7.40 x 6.00 x 3.15	7.40 x 6.60 x 3.10	6.75 x 6.00 x 3.35	7.20 x 6.10 x 3.00
CLASSROOM 3	7.40 x 6.00 x 3.15		6.75 x 6.00 x 3.35	
CLASSROOM 4	7.40 x 6.00 x 3.15		6.75 x 6.00 x 3.35	
CLASSROOM 5	6.00 x 7.00 x 3.15			
CLASSROOM 6	7.45 x 6.20 x 3.15			

**TABLE 4.5.1. CLASSROOM DIMENSIONS**

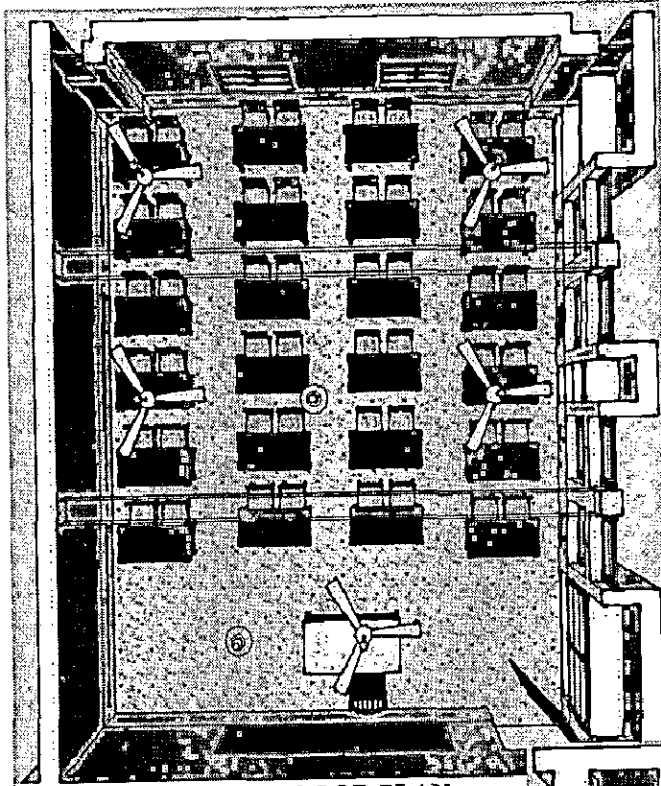
SPATIAL DIMENSIONS (LxBxH)	SCHOOL 1	SCHOOL 2	SCHOOL 3	SCHOOL 4
LABORATORY 1	15.00 x 6.30 x 3.15	13.50 x 6.60 x 3.10	10.20 x 6.00 x 3.35	7.20 x 6.10 x 3.00
LABORATORY 2		13.50 x 6.60 x 3.10	10.20 x 6.00 x 3.35	7.20 x 6.10 x 3.00

**TABLE 4.5.2. LABORATORY DIMENSIONS**

The classrooms that were studied were all rectangular in plan. They ranged in area from 40.5sq.mts to 48.84sq.mts. Curtains were provided only in the classrooms of school 3. The distribution of light in all the examples was in the recommended range of 200 – 500 lux (according to National Building Code 2005)

Floor area for laboratories ranged from 43.92sq.mts to 94.5sq.mts. Curtains were provided only in schools 2 and 3. Light distribution was in the recommended range except in one laboratory in school 4.

## 4.5.1 SCHOOL 1 – ADARSH BAL NIKETAN SENIOR SECONDARY SCHOOL



4.5.1. CLASSROOM 1 FLOOR PLAN

Classrooms 1, 2, 3, 4 have similar floor plans and similar plan forms. They are located on opposite sides of a double side corridor. These classrooms are the only ones having windows on two walls, allowing for more even distribution of light into the classrooms, with desktops further from the windows having lesser but nonetheless, adequate lighting.

Length = 7.40mts,

Width = 6.00mts,

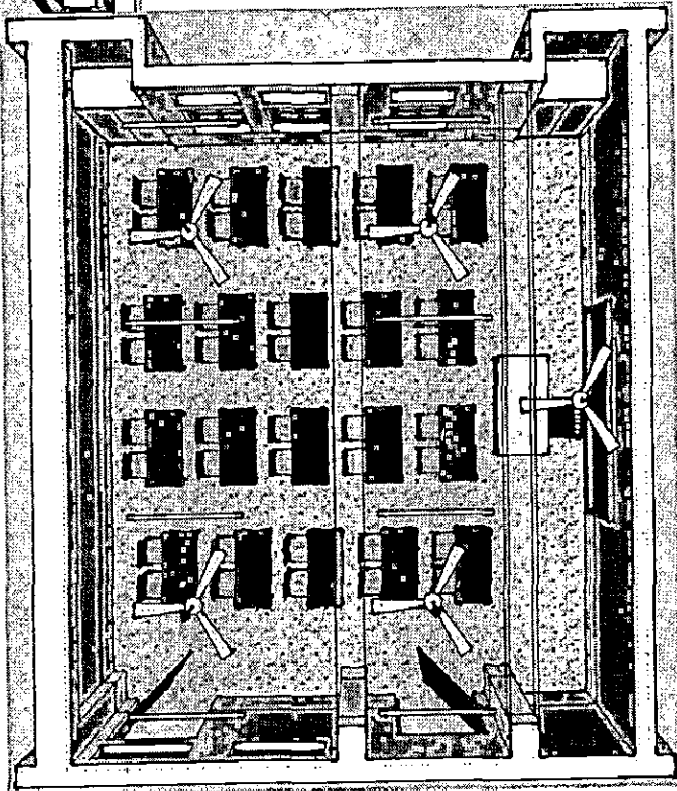
Height = 3.15mts

Classroom 5 has a wider floor plan compared to earlier examples. Windows have been provided only on the South West walls. The North East wall has ventilators provided to bring in light. This classroom is located along a single side corridor which is open towards the North East side.

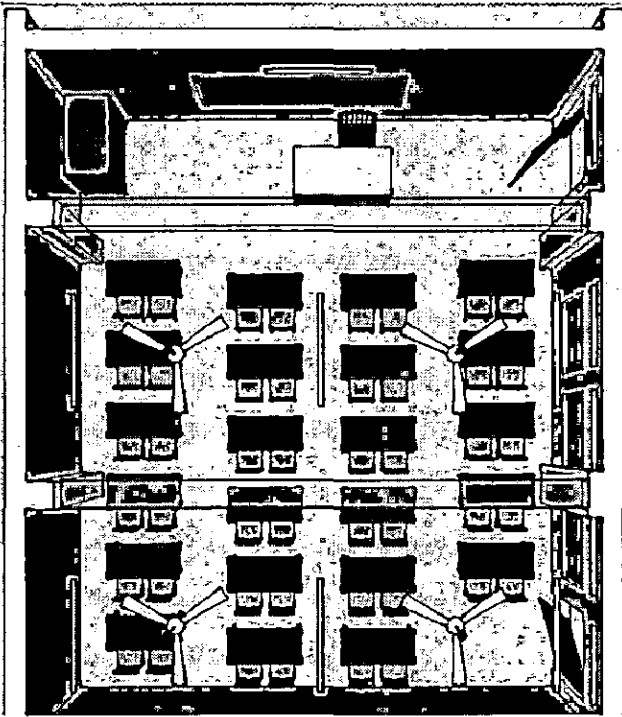
Length = 6.00mts

Width = 7.00mts

Height = 3.15mts



4.5.2. CLASSROOM 5 FLOOR PLAN



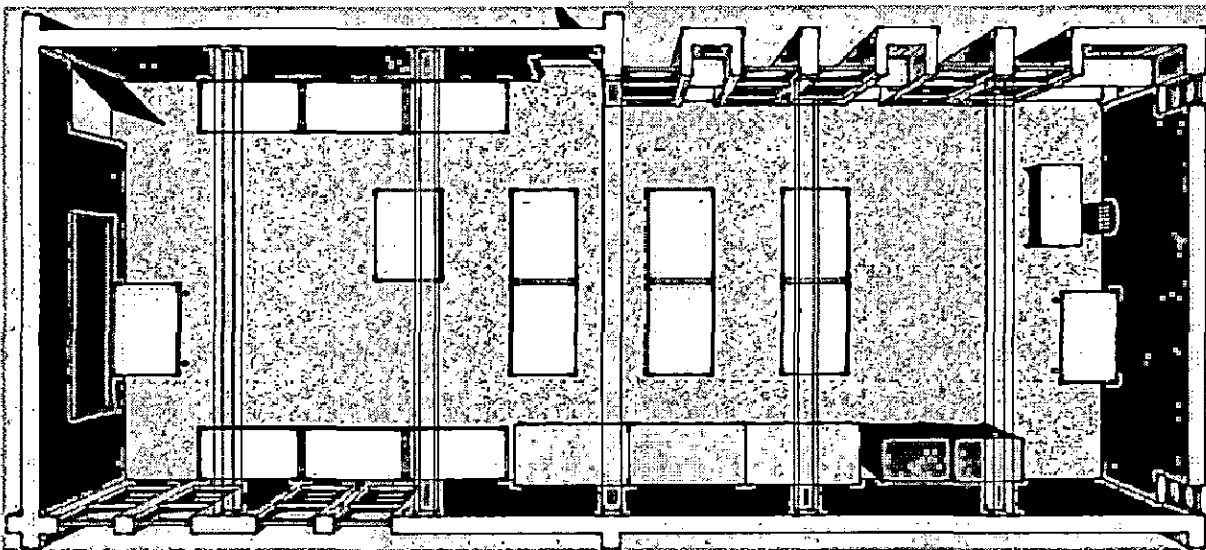
4.5.3. CLASSROOM 6 FLOOR PLAN

Classroom 6 has the largest floor area amongst the selected examples. Windows are provided only on the North West walls. This classroom is also located along a single side corridor that opens to the North West side so it is bit darker than the other examples.

Length = 7.45mts

Width = 6.20mts

Height = 3.15mts



4.5.4. LABORATORY PLAN

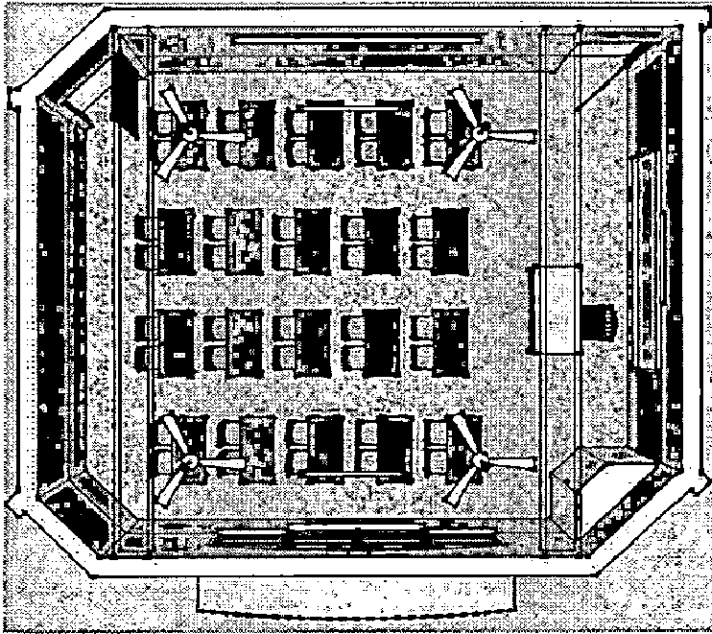
The laboratory is rectangular in plan. Windows are provided along half of the South East facing walls and along half of the north-west facing walls. The North West windows open into a single side corridor open towards the North West. Lighting is bit uneven in this laboratory but it is balanced by artificial lights.

Length = 15.00mts

Width = 6.30mts

Height = 3.15mts

## 4.5.2 SCHOOL 2 – FATHER AGNEL SCHOOL, NOIDA



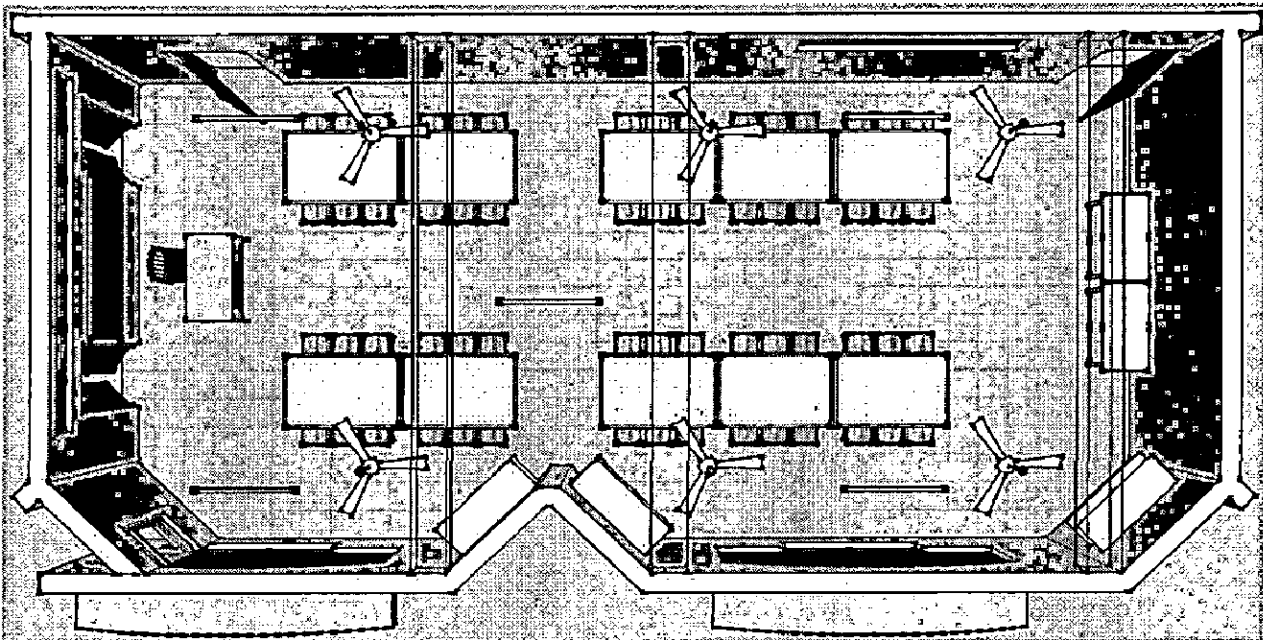
Classrooms 1 and 2 have similar plans that are mirror-images of each other. One window is provided on the South wall and has a 60cm sunshade on it.

Length = 7.40mts

Width = 6.60mts

Height = 3.10mts

4.5.5. CLASSROOM PLAN



4.5.6. LABORATORY PLAN

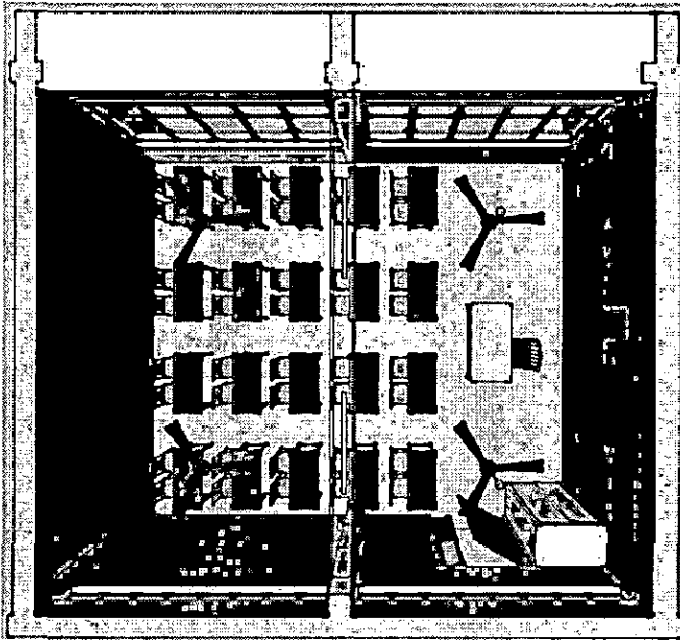
Laboratories 1 and 2 have both similar mirrored plans. Windows are provided on the south wall with 60cm sunshading

Length = 13.50mts

Width = 6.60mts

Height = 3.10mts

4.5.3 SCHOOL 3 - FATHER AGNEL SCHOOL, NEW DELHI



All classrooms in this school are of the same plan form and are mirrored images of each other. Windows are placed on the North West walls or the South East walls depending on position of the classroom.

Length = 6.75mts

Width = 6.00mts

Height = 3.35mts

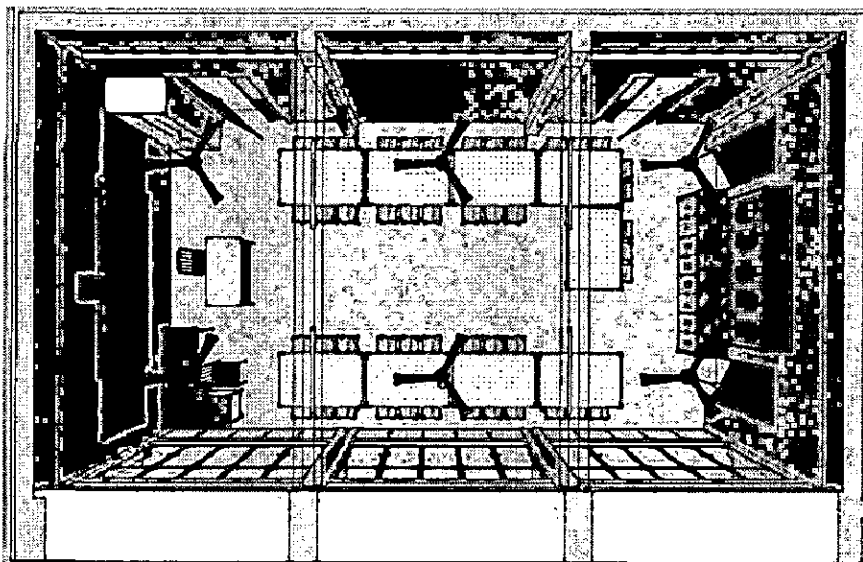
4.5.7. CLASSROOM PLAN

Both laboratories are located at opposite sides of a double side corridor and have same plan. Windows are provided on South East wall or North West wall.

Length = 10.20mts

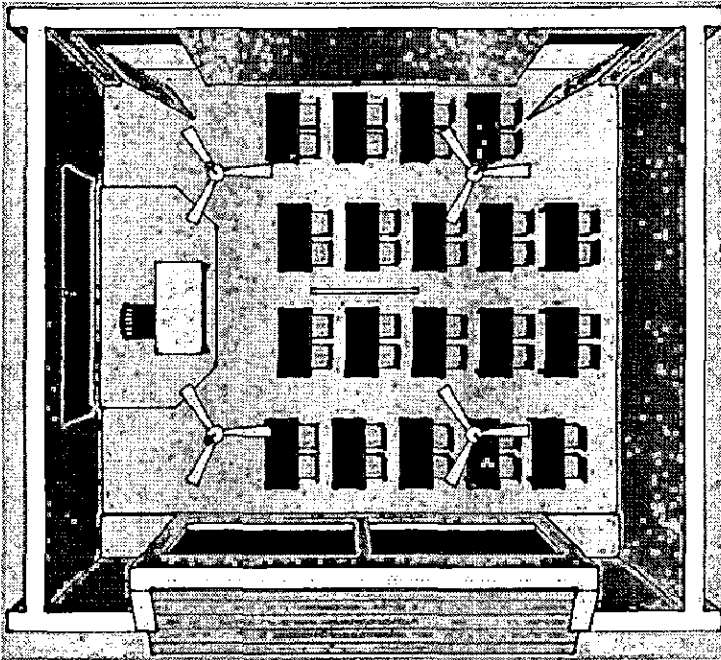
Width = 6.00mts

Height = 3.35mts



4.5.8. LABORATORY PLAN

4.5.4 SCHOOL 4 – KERALA SCHOOL, NEW DELHI



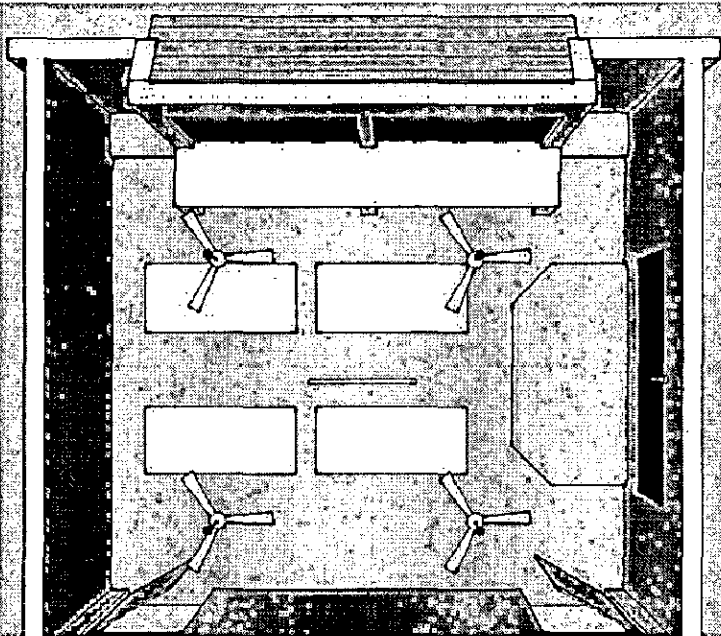
All selected rooms in school 4 have the same dimensions. Selected classrooms were on opposite sides of a double side corridor. Windows were placed on South East wall and North West wall.

Length = 7.20mts

Width = 6.10mts

Height = 3.00mts

4.5.9. CLASSROOM PLAN



The laboratory plan form is rectangular. Windows are provided North West wall. They have been provided with sunshades too, that mimic traditional sloping roofs found in buildings in Kerala.

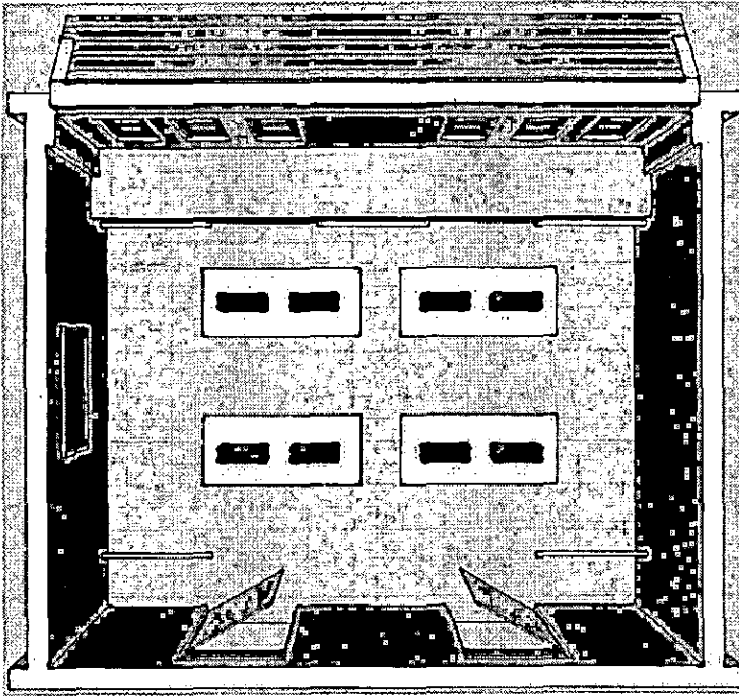
Length = 7.20mts

Width = 6.10mts

Height = 3.00mts

4.5.10. LABORATORY PLAN





4.5.11. LABORATORY 2 FLOOR PLAN

Laboratory 2 plan is similar to 1st laboratory except for the provision of windows. Light ingress is deliberately limited in this example, by implementing smaller windows with frosted glass.

Length = 7.20mts

Width = 6.10mts

Height = 3.00mts

All the classrooms and laboratories observed were regular and rectangular in plan except in school 2. In all the examples it was observed that illuminance levels were highest towards the window sides and much lesser towards the corners, although average illuminance was above acceptable levels. Room depth ranged from 6.00mts to 7.00mts. Room height was also in a narrow range of 3.00mts to 3.35mts. Lengths were in larger range of variation, 6.00mts to 7.45mts for classrooms and from 7.20mts to 15.00mts for laboratories.

## 4.6 WINDOW TO FLOOR AREA RATIO

WINDOW TO FLOOR AREA RATIO (SQ.MTS)	SCHOOL 1	SCHOOL 2	SCHOOL 3	SCHOOL 4
CLASSROOM 1	9.93 : 44.2 22.46 %	8.46 : 47.5 17.81 %	11.76 : 40.5 29.03 %	9.58 : 43.9 21.82 %
CLASSROOM 2	9.93 : 44.2 22.46 %	8.46 : 47.5 17.81 %	11.76 : 40.5 29.03 %	9.58 : 43.9 21.82 %
CLASSROOM 3	9.93 : 44.2 22.46 %		11.76 : 40.5 29.03 %	
CLASSROOM 4	9.93 : 44.2 22.46 %		11.76 : 40.5 29.03 %	
CLASSROOM 5	5.29 : 42 12.59 %			
CLASSROOM 6	5.31 : 46.2 11.49 %			

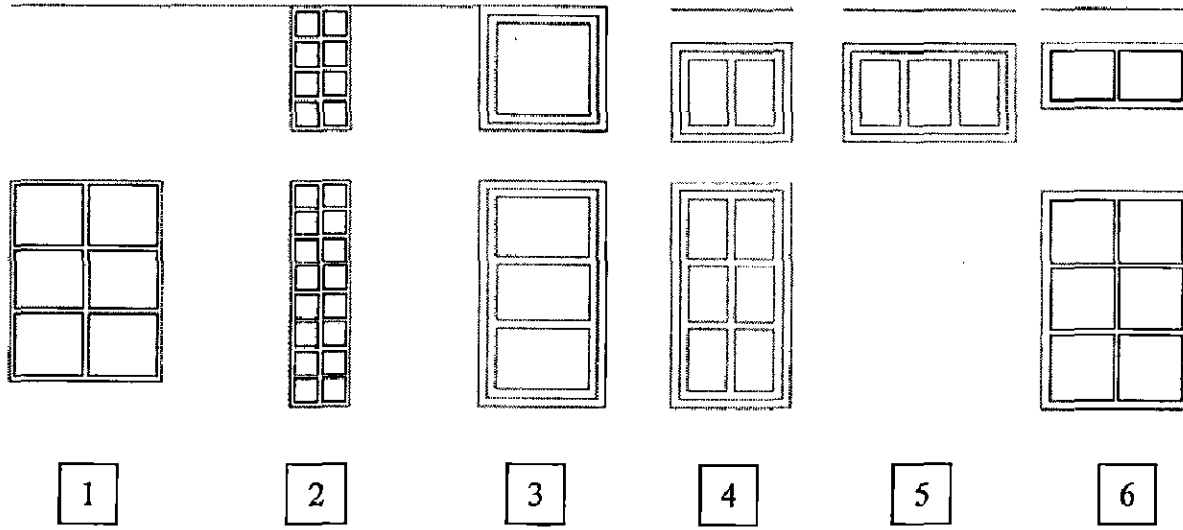
TABLE 4.6.1. WINDOW TO FLOOR AREA RATIO FOR CLASSROOMS

WINDOW TO FLOOR AREA RATIO (SQ.MTS)	SCHOOL 1	SCHOOL 2	SCHOOL 3	SCHOOL 4
LABORATORY 1	17.00 : 94.5 17.98 %	14.77 : 86.4 17.09 %	17.64 : 61.2 28.82 %	9.58 : 43.9 21.82 %
LABORATORY 2		14.77 : 86.4 17.09 %	17.64 : 61.2 28.82 %	5.73 : 43.9 13.05 %

TABLE 4.6.2. WINDOW TO FLOOR AREA RATIO FOR LABORATORIES

The window to floor area ratio in classrooms ranged from 11.49% to 29.03%. For ideal level of illumination in any space, the window to floor area ratio must be at least 20%. It was observed that in spaces having far below the minimum 20% ratio, average illumination levels were below the recommended levels quoted by the national building code. However in the spaces where the ratio was maximum, in some cases, the illumination levels were found to be too high at points near the window, such that it causes glare on the desktop surface. The level of comfort, while writing, was good in most of the examples.

**SCHOOL 1 – ADARSH BAL NIKETAN SENIOR SECONDARY SCHOOL**

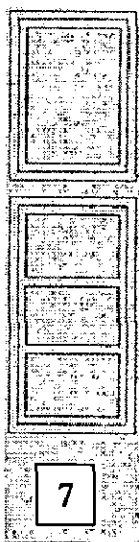


**4.6.1. ELEVATIONS OF DIFFERENT TYPES OF WINDOWS USED IN CLASSROOMS**

There are six different types of windows used in the six classrooms of school 1. Window 1, 2 and 3 are used in classrooms type 1, 2, 3 and 4. Window 1 doesn't have any sunshading and window types 2 and 3 are recessed. Window 4 is used in classroom type 5 and it is recessed. Window 5 is placed on the corridor side of classroom type 5 and isn't shaded separately. Window 6 is used on the corridor side of classroom type 6 which is the only classroom to have fenestrations on the corridor side alone.

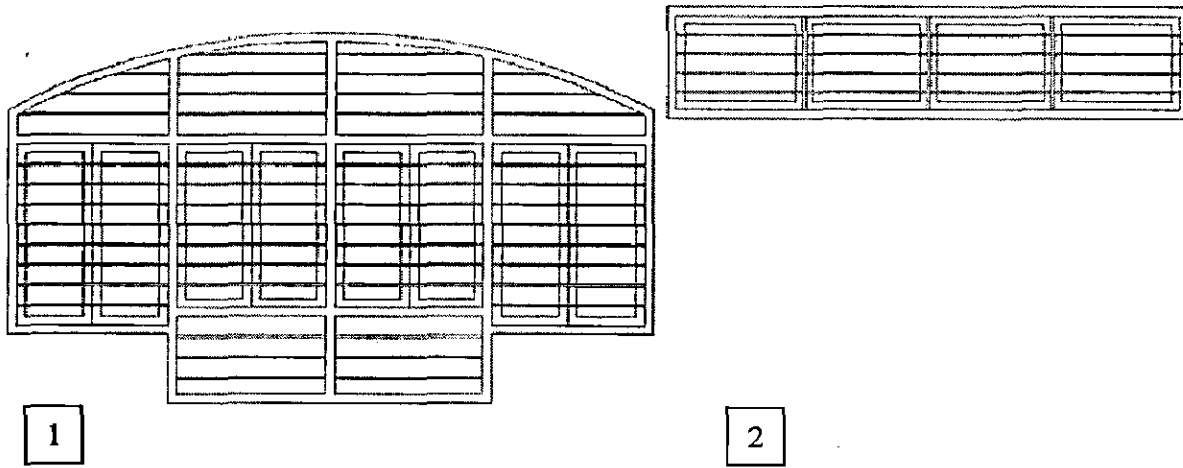
Window 7 is used in the laboratory. It is provided in North West facing wall and South East facing wall. Windows in the North West wall open into a passageway so are not shaded. Windows in the South East wall are recessed. Sill levels range from 75cms to 90cms. Sill heights are 210cms in all examples. In some classes, a ventilator has been provided over the window to let in more light. All windows use clear float glazing. Window 3 and 7 are wooden framed and the rest are steel framed.

Usage of window 1, 2 and 3 gives window to floor area ratio 22.46%. Classroom 5 uses window 4 and 5 and has window to floor area ratio 12.59%. Classroom 6 uses window 6 has window to floor area ratio 11.49%. Average illumination in classroom type 5 and type 6 is much lesser than for classroom types 1, 2, 3 and 4. Laboratory has window to floor area ratio of 17.98%.



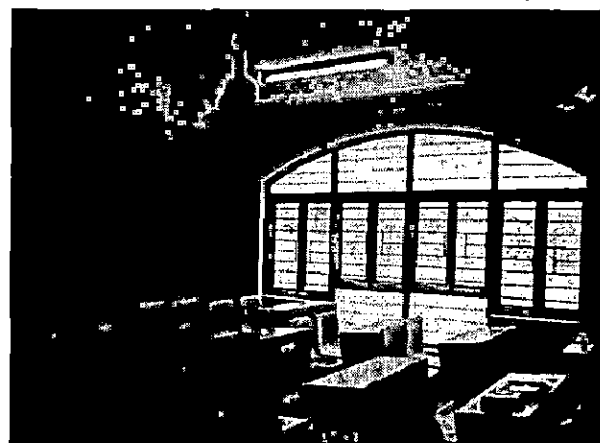
**4. 6.2. ELEVATIONS OF WINDOW USED IN LABORATORIES**

## SCHOOL 2 – FATHER AGNEL SCHOOL NOIDA

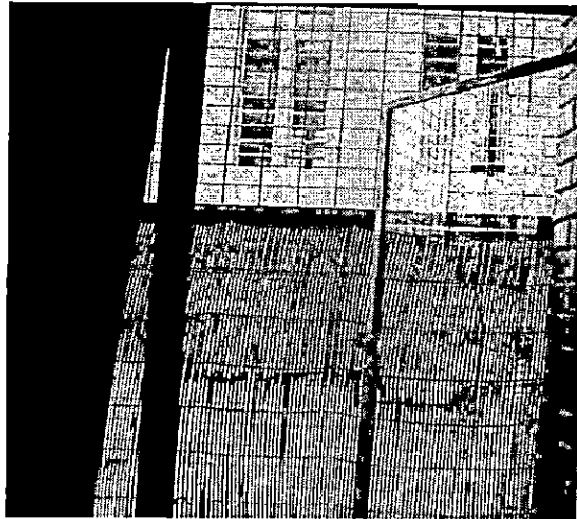
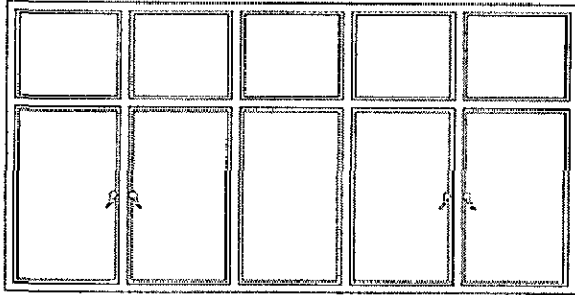


#### 4.6.3. ELEVATIONS OF DIFFERENT TYPES OF WINDOWS USED IN CLASSROOMS AND LABORATORIES

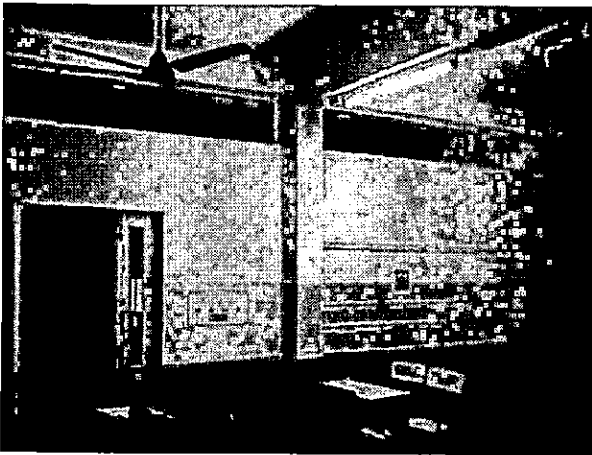
Only one type of window is used in school 2 for all classrooms and laboratories. The window is 360cms wide and half of this has a sill level of 50cms and other half has sill level 90cms. The top of the window is arched, with a height of 260cms. Window area is 6.51sq.mts. The ventilator is provided on the corridor facing walls. Sill height is 210cms and lintel height is 275cms. Window to floor area ratio is 17.81% for classrooms and 17.09% for laboratories. Classrooms have average illumination within the recommended levels. Laboratories are better illuminated even though window to floor area ratio is almost same. This is because the labs are located on the topmost floors and hence the windows are not blocked shade of nearby buildings.



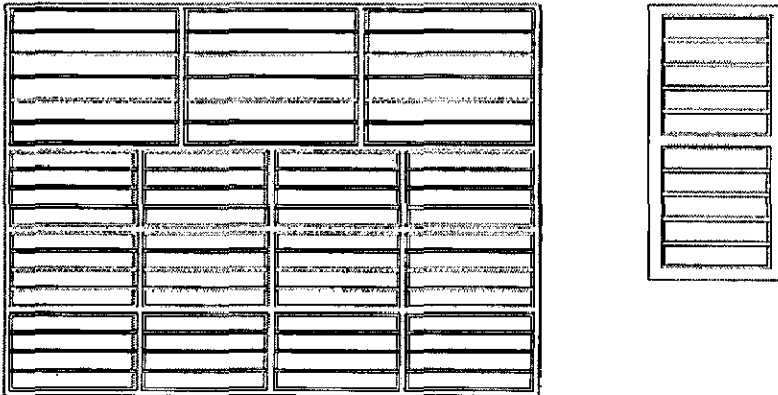
#### 4.6.4. LABORATORY AND CLASSROOM ILLUMINATION

**SCHOOL 3 – FATHER AGNEL SCHOOL, NEW DELHI****4.6.6. BAMBOO STRIP SHADING****4.6.5. ELEVATION OF WINDOW**

Only one type of window is used in school 3 for all classrooms and laboratories. Window area is 5.88sq.mts. Window to floor area ratio is 29.03% for classrooms and 28.82% for laboratories. Classrooms have average illumination above the recommended levels. Artificial lighting only serves to supplement high levels of natural light, whenever it is required.

**4.6.7. CLASSROOM IMAGES**

**SCHOOL 4 – KERALA SCHOOL, NEW DELHI**



**4.6.8. TYPES OF WINDOWS USED IN CLASSROOMS AND LABORATORIES**

Only one type of window is used in school 5 for all classrooms and laboratories. Window area is 5.88sq.mts. Window to floor area ratio is 21.82% for classrooms and laboratory 1. Laboratory 2 has window to floor area ratio of 13.05%.



**4.6.9. ILLUMINATION IN LABORATORIES 1 AND 2**

#### 4.7 AVERAGE ILLUMINATION LEVELS

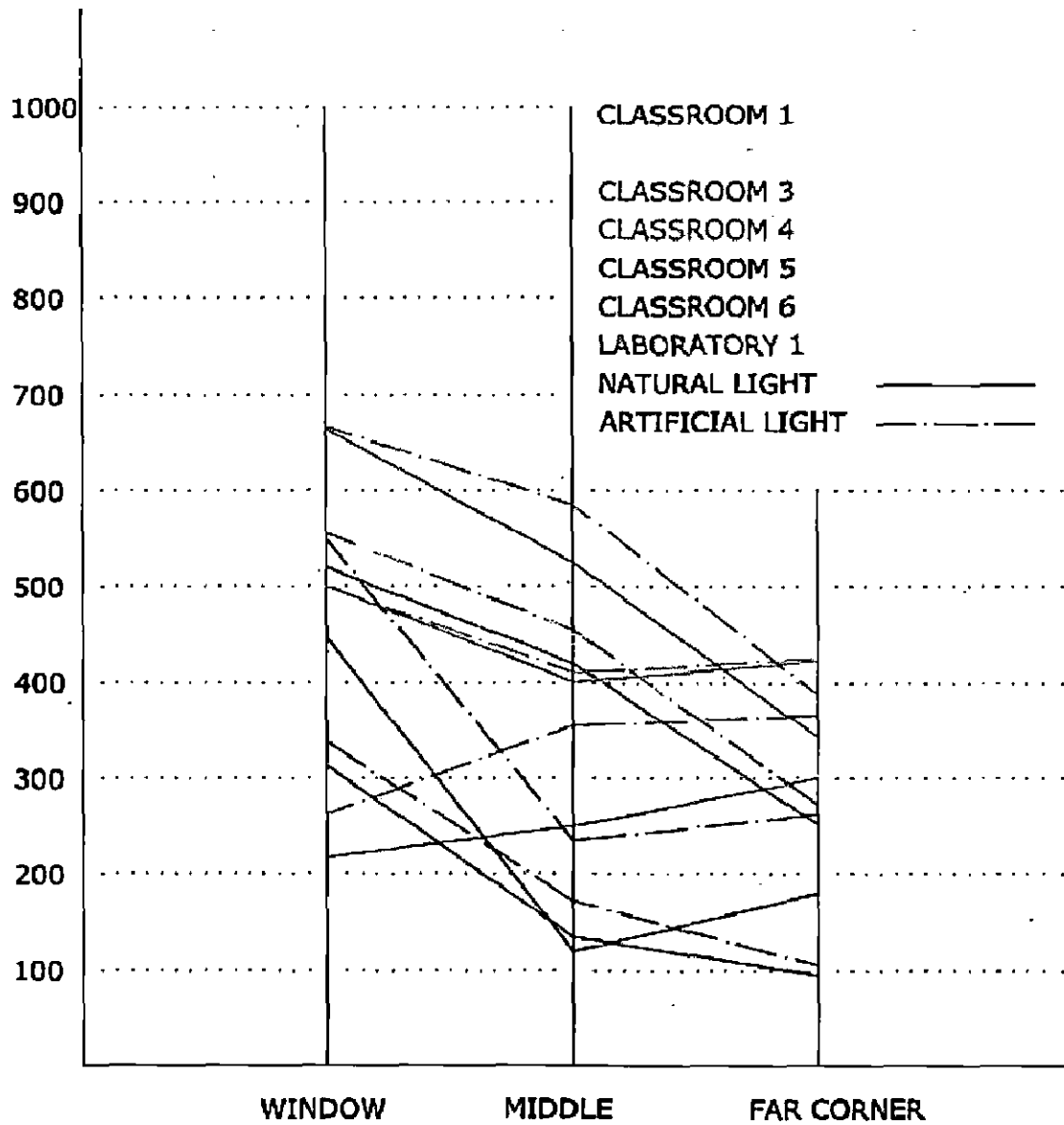
AVERAGE LUX	SCHOOL 1	SCHOOL 2	SCHOOL 3	SCHOOL 4
CLASSROOM 1	348.78	280.25	458.71	570.67
CLASSROOM 2	384.07	278.21	285	392.89
CLASSROOM 3	436.32		863.82	
CLASSROOM 4	389.5		1013.10	
CLASSROOM 5	221.89			
CLASSROOM 6	165.71			

**TABLE 4.7.1. AVERAGE ILLUMINATION TABLE FOR CLASSROOMS**

AVERAGE LUX	SCHOOL 1	SCHOOL 2	SCHOOL 3	SCHOOL 4
LABORATORY 1	225.28	601.21	1065.35	542.17
LABORATORY 2		555.07	596.46	71.93

**TABLE 4.7.2. AVERAGE ILLUMINATION TABLE FOR LABORATORIES**

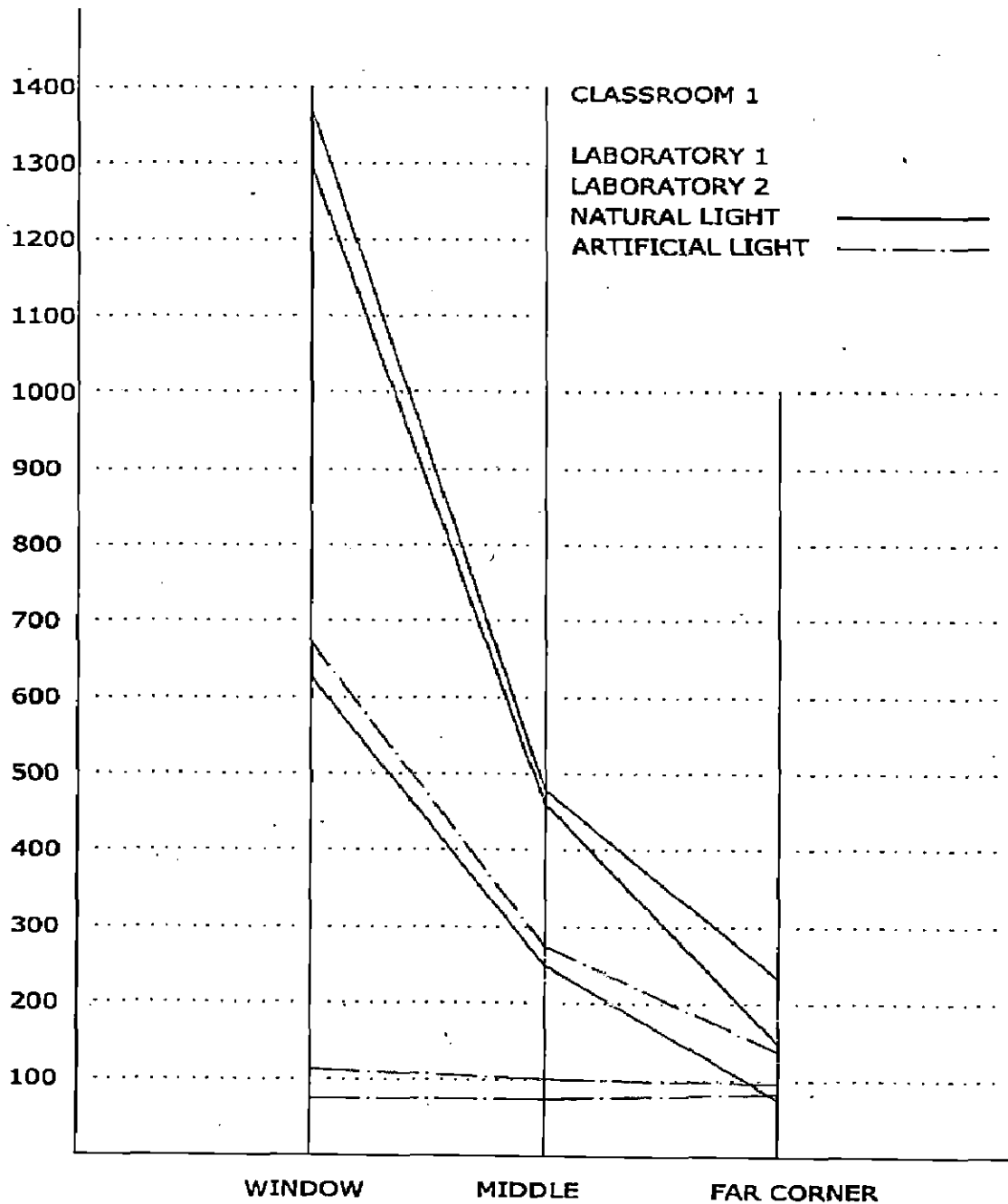
Based on the average illumination levels in the classrooms and laboratories, it is observed that illumination levels are within or above the recommended levels. However in some of the examples, when the illumination levels are measured at separate points, it is seen that the light levels sharply taper off towards the far corners of the room and they may be uncomfortably high towards the window corners. It may be necessary to cut the amount of light at the window corners and enhance light at the far corners with artificial sources.



4.7.1. ILLUMINATION GRAPH FOR SCHOOL 1

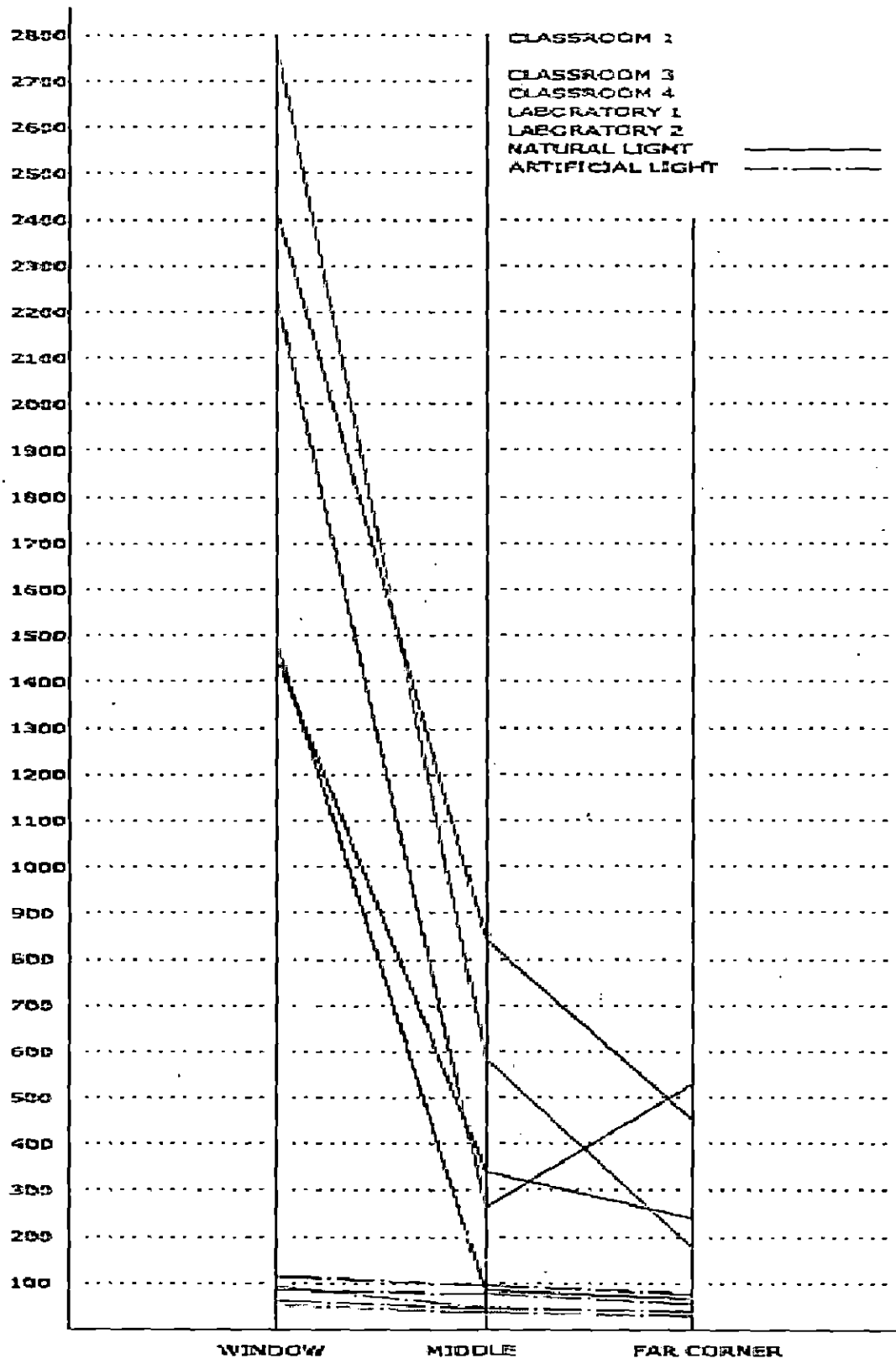
The graph shows that for school 1, the illumination levels are within the acceptable limits and since there are no blinds, artificial lighting provided just supplements the natural light. Positions of fenestrations, with respect to building orientation, affect the spread of light through the space. Here, since all the classrooms except classroom 6 have fenestrations on both sides, light levels are more evenly distributed.





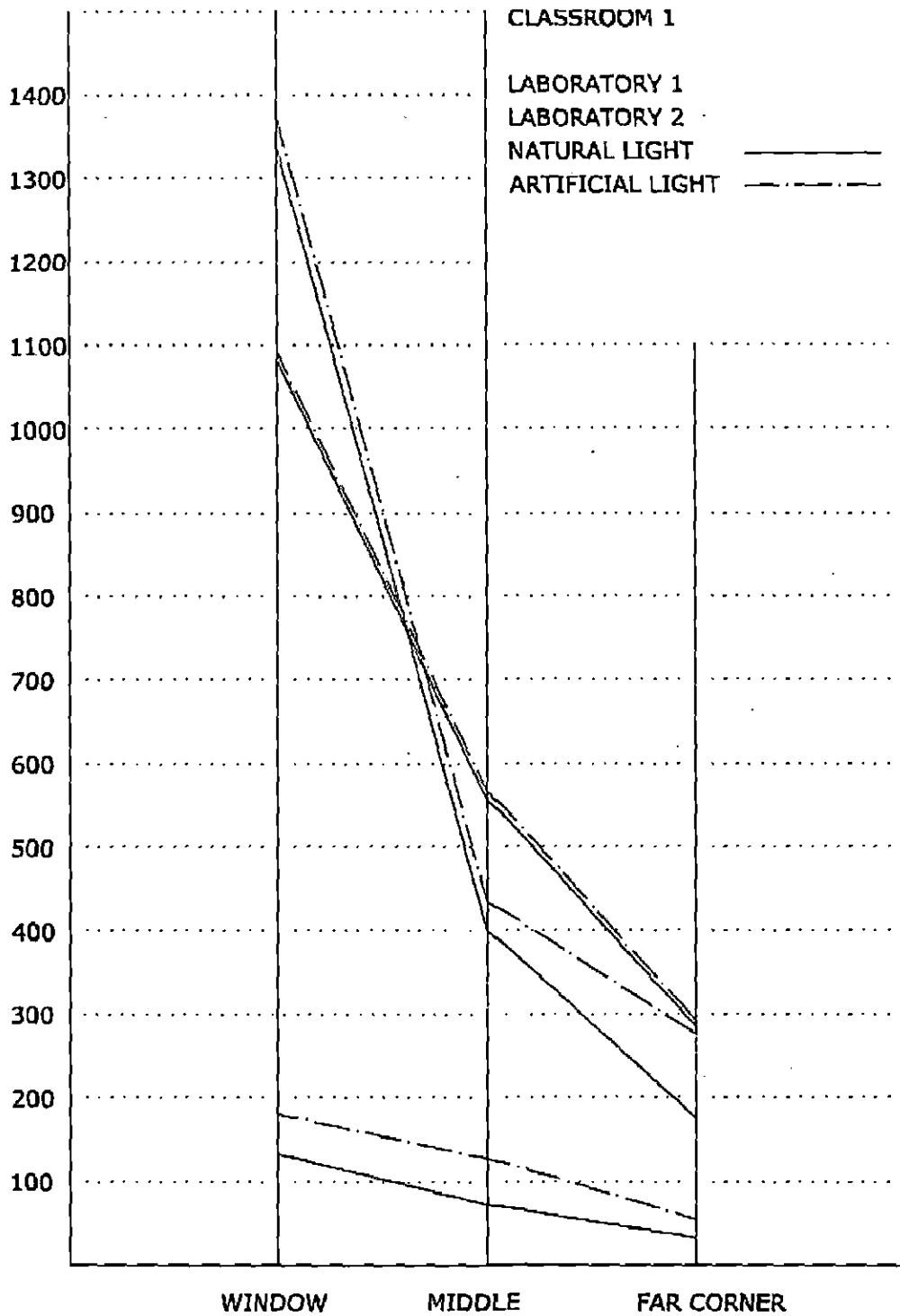
4.7.2. ILLUMINATION GRAPH FOR SCHOOL 2

In school 2, distribution of light is very high on window side and much lower towards the far corner. Only one side of the spaces has been provided with windows and so distribution of light is highly uneven. Window side seats experience diffused glare. Both laboratories have curtains and on drawing these, the average illumination levels drop to less than the recommended levels.



4.7.3. ILLUMINATION GRAPH FOR SCHOOL 3

School 3 has similar light distribution in the spaces as in school 2. Curtains are provided in all the spaces. Artificial lighting isn't enough on its own. Window side glare is uncomfortably high and attempts have been made to cut it down using bamboo shades.

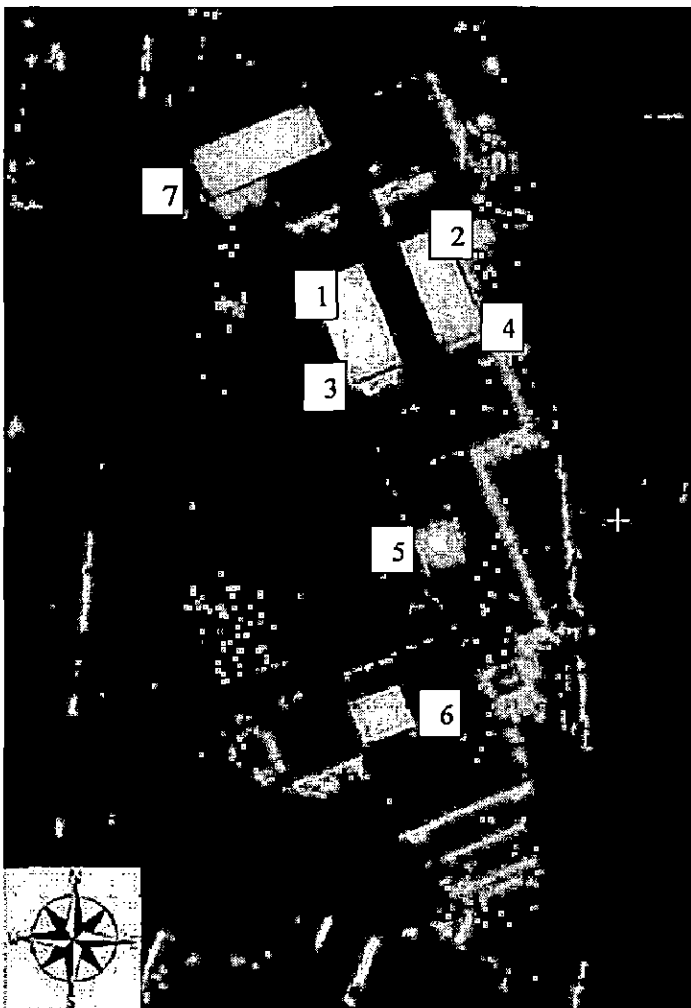


4.7.4. ILLUMINATION GRAPH FOR SCHOOL 4

In school 4, distribution of light is very high on window side and much lower towards the far corner. One of the spaces has been provided with windows and so distribution of light is much lesser than recommended even with the lights turned on. Other rooms have higher illumination which is supplemented by artificial lighting.

## 4.8 ANALYSIS

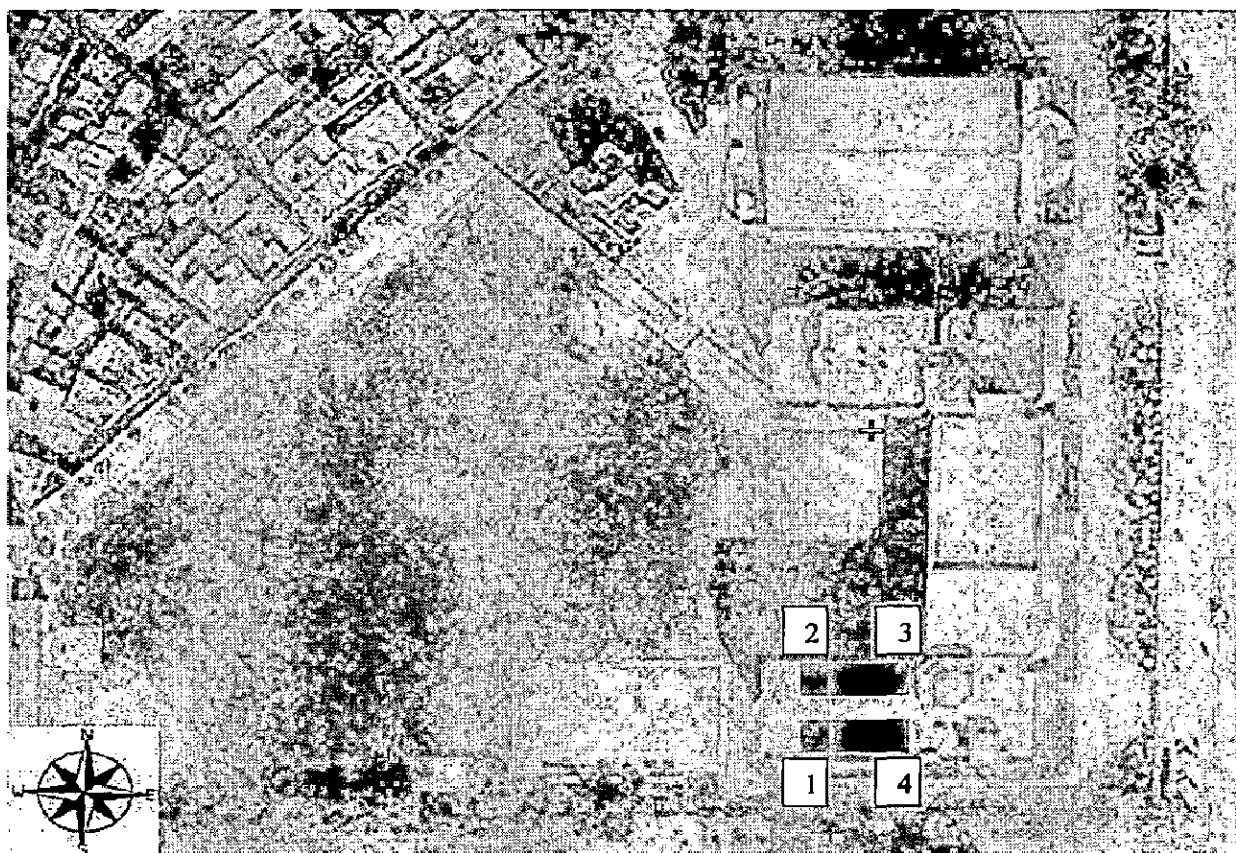
**SCHOOL 1** – Six classrooms were analyzed and of these, five can be considered well lit. The spread of light and average illumination levels were in the recommended range itself. The window to floor area ratio was 22.46% for classrooms 1, 2, 3 and 4. It was 12.59% for classroom 5 and 11.49% for classroom 6. Fenestrations were provided in two walls in classrooms 1, 2, 3, 4 and 5. Classroom 6 had fenestrations on only one side that opened into a single side corridor. It also had lowest illumination levels of the selected examples. It was provided with 6 tubelights to counter the lack of natural lighting. The windows face North West but they are affected by the large sunshading provided by the corridor. In all other classrooms observed, it was seen that windows mostly open outwards instead of into the building itself.



4.8.1. ORIENTATION OF OBSERVED SPACES

The highlighted areas show the locations and orientations of the observed spaces. Areas labeled 1 to 5 are where classrooms with fenestrations on two walls are located. The laboratory (7) has also got fenestrations on two walls. These are positioned to light the space as required instead of being just symmetrical. Maintenance of fixtures will help to improve the quality of light inside the classrooms. Natural light is supplemented by artificial lighting in all spaces except classroom 6 in which, it is a necessity because of low levels of natural lighting in normal operating hours.

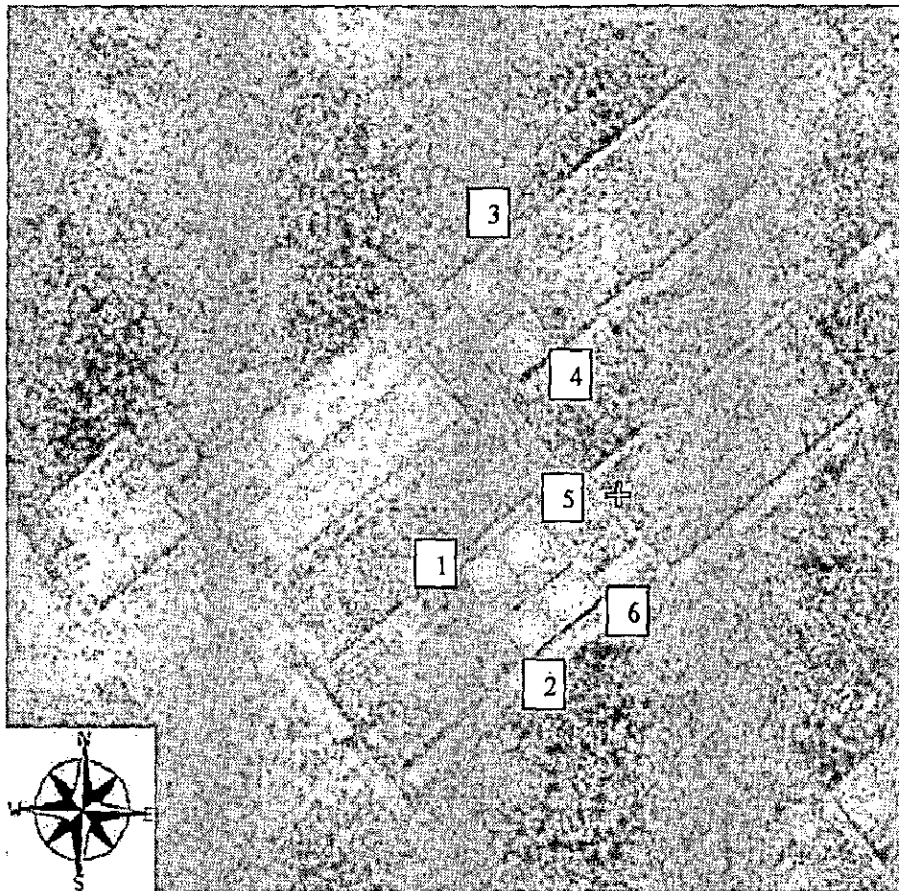
**SCHOOL 2** – Two classrooms and two laboratories were analyzed. Window to floor area ratio were nearly the same with it being 17.81% in classrooms and 17.09% in laboratories. The average illumination levels were within the recommended range. But the spread of light is highly varied with the points in proximity to the window having very high illumination and the far corners having very less. Gloss paint finish is used in the spaces but they don't create any distracting reflections. Curtains are provided to cut daylight as projectors are also provided in the classrooms. Room orientations are perfectly aligned to the cardinal directions.



**4.8.2. ORIENTATION OF OBSERVED SPACES**

Highlighted areas show classrooms (1 and 2) and laboratories (3 and 4). Despite having nearly the same window to floor area ratio, same type of fenestrations and same interior finish, illumination levels at the window side were found to be nearly twice for laboratories as compared to classrooms. It was concluded that the height of the room with respect to ground, also makes a difference, as the angle of sunlight will be different with height. Presence of surrounding buildings can also affect quality of light entering the space if it is casting a shadow on the observed space.

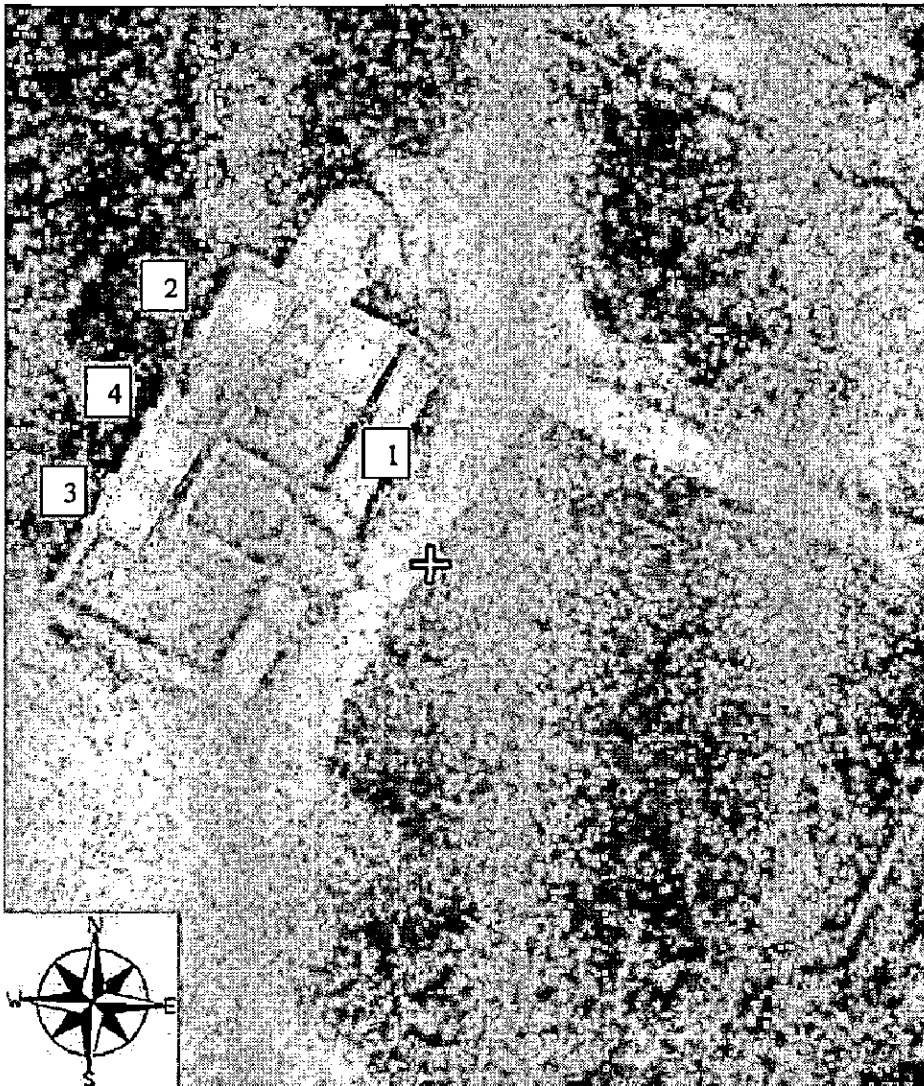
**SCHOOL 3** – Four classrooms (1, 2, 3, and 4) and two laboratories (5 and 6) were analyzed. Window to floor area ratio was the highest amongst the observed examples. It was 29.03% for classrooms and 28.82% for laboratories. The average illumination and distribution of light data showed a lot of variety depending on the plan form and orientation of the space. Blinds were provided in all the observed spaces. All classrooms had projectors and artificial lighting is intentionally set at low levels as daylighting levels are very high.



#### 4.8.3. ORIENTATION OF OBSERVED SPACES

All observed spaces had very high illumination levels near the windows and far lesser amounts of light towards the far corners. Illumination levels were more for South East facing spaces and also increased significantly with the floors on which the spaces were located. These values were significantly lesser for North West facing spaces. Blinds have been provided on South East facing ground floor spaces to reduce amount of glare caused by daylight. Same blinds have been provided on North West facing spaces on ground floor for symmetry but they are not as dense as the blinds on the South East openings. Again, classrooms have been fitted with projectors, so artificial lighting levels are low when curtains are drawn.

**SCHOOL 4** – Two classrooms and two laboratories were analyzed. Both classrooms and one of the laboratories had the same window to floor area ratio of 21.82%. Distribution of light is again high at windows and lesser towards the far corners. Average illumination was in the recommended range. Classroom (1) facing South East has significantly more illumination levels than classroom (2) that faces North West. But laboratory (3) faces North West too and light levels are higher. This is due to the surface treatment of the furniture inside. The laboratory uses furniture with light colored matte finishes that reflect more light than the darker furniture of the classrooms. The other laboratory (4) has a lower window to floor area ratio of only 13.05% and uses frosted glazing. The intention is to minimize ingress of light because of light-sensitive chemicals stored in this laboratory. Artificial lighting hardly affects the spread of light in spaces 1, 2 and 3. In space 4, some significant difference is observed in the illumination level with tubelights on. None of the spaces have window blinds.



**4.8.4. ORIENTATION OF OBSERVED SPACES**

## **5 CHAPTER 5 - CONCLUSIONS AND RECOMMENDATIONS**

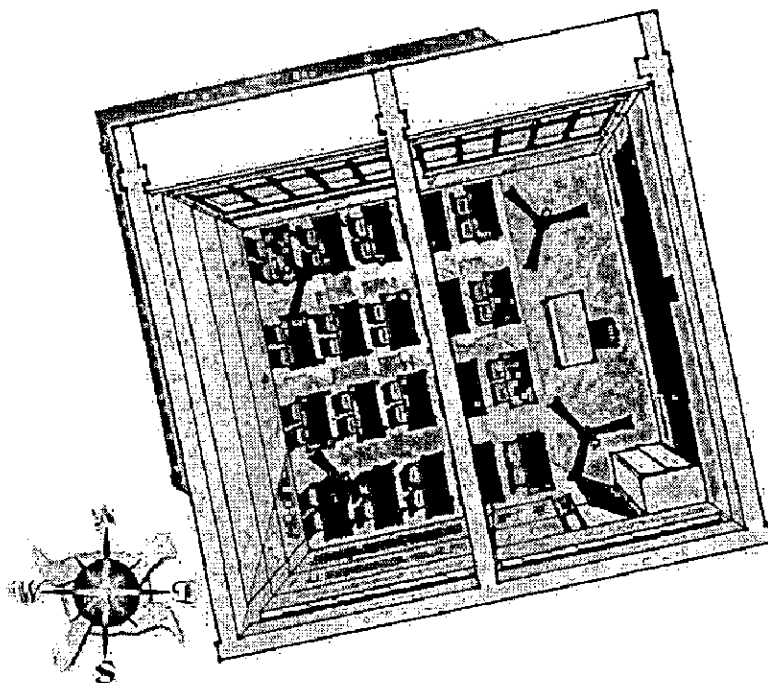
### **5.1 INTRODUCTION**

Guidelines for lighting design in school buildings are suggested based on the literature review and the analysis of case studies to ensure even distribution of light within the classrooms and provide a pleasant visual environment.

*Guidelines deal with the various parameters that affect quality and quantity of light inside the classrooms.*

### **5.2 ORIENTATION**

- Ideally fenestrations should face Northern direction when possible. This will reduce heat load and light coming in will be diffused, compared to the South light. North facing classrooms should have room orientation from west to east to have light coming in from the left side.
- South facing classrooms should have room orientation from east to west to have light come in from the left.
- Window facades should preferably not face east or west due to high heat loads.

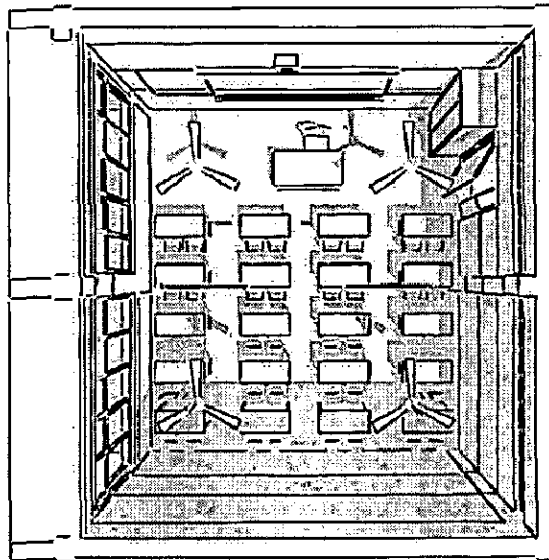


### **5.1. ORIENTATION**



### 5.3 PLAN AND PLAN-FORM

- Rectangular or square plans in which Length > width are preferred as reflections on the blackboard or whiteboard can be distracting for students sitting on outer seats. For classrooms having fenestrations only on one side, width of room should not exceed 6mts.
- Different plan shapes can cause distraction because the different angles at which the walls are placed can cause some walls to appear brighter than the rest.



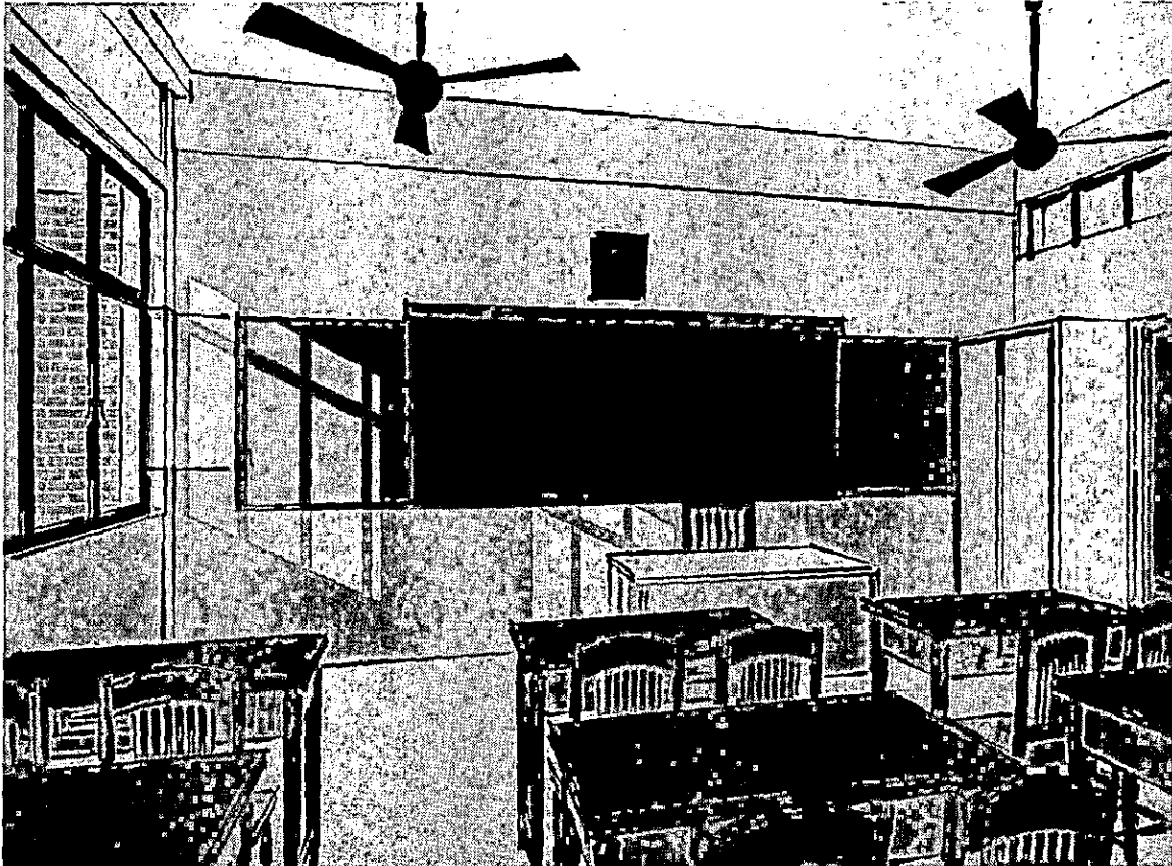
### 5.2. PLAN FORM

#### 5.4 FURNITURE

- Glossy finished furniture should be avoided as they create distracting reflections.
- Light colored furniture should not be placed near windows as they cause glare too.
- Dark furniture causes large amount of contrast and should be avoided. Medium colored furniture can be used as they won't cause distracting glare or contrast in direct sunlight.

### 5.5 INDOOR SURFACE TREATMENT

- Walls should have light colors so that they will make the room appear larger. Inner walls should not have gloss finish. Dark colors are to be avoided.
- Ceilings should be light colored (preferably white) to reflect from fixtures and also reflect diffused light.
- Light colored floors can also act as source of diffused light but they should not have gloss finish.

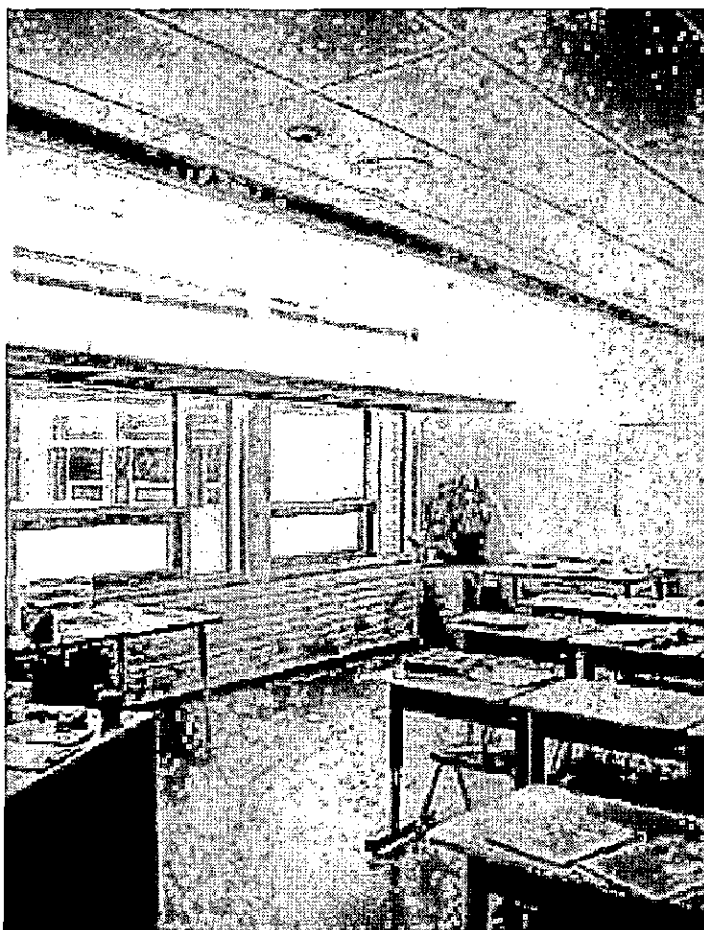


### 5.3. SURFACE TREATMENT

### 5.6 FENESTRATION AND DETAILS

- Sill height of windows should be 90cms. It should be above the tabletop height. Very large windows will create distraction for users sitting at the window side.
- Ideally there should be fenestrations on two walls so that distribution of light in the room is more even rather than being concentrated near the window side. Ventilators on the far side wall can bring in light from the corridor side. But these are more effective when the corridor is well lit artificially or naturally.
- Ventilators should be large enough to allow light in come in properly. They can act as diffused light source if provided with frosted glazing.

- Windows on adjacent walls are effective in even distribution of light. But if provided on adjacent walls, windows on the rear wall should be smaller than the ones on the left side of the class; otherwise they will cast a shadow towards front for users who are seated at the back benches.
- Windows on the side walls should have clear glazing and not frosted glazing. They should provide clear view to the exterior. Distorted glazing will create confusion about time orientation.
- Lintel height for windows should not be less than 60cms from the ceiling as it creates a sense of distortion of space, by creating the illusion that the room is taller than it is. The sense of proportion of the room should not be lost.
- Window to floor area ratio must be maintained near 20%.
- Light shelves can be provided for rooms in which far corners are not getting sufficient light.



**5.4. APPLICATION OF LIGHT SHELVES**

School buildings fall into the category of spaces in which the quality and quantity of light entering the rooms has a direct impact on the performance of users. Too much light can have negative impact on performance, just the same as lack of lighting would have. There are several architectural parameters that affect the quality of lighting inside a space. The parameters range from plan-form and interior surface treatment to building orientation. These parameters can be controlled by an architect by the design process.

Natural light is a dynamic component of an environment. It can add vibrancy and colour to an otherwise dull space. Artificial light is a static component that can be directly controlled by the designer. However it doesn't have the same effect that a dynamic light source will have upon a space. Most of the newer lighting techniques aim to achieve efficiency by integrating natural light along with artificial lighting systems. In case of school buildings, most schools have a working schedule that runs during daytime and hence can make the most of the abundant natural light available.

Parameters that affect natural light inside a space are:-

**Building orientation, Plan form, dimensions of space, surface treatment, window area and details, position of surrounding buildings and vegetation.**

All these factors can be controlled by an architect through the design itself. When designing a school building, the orientation of the building has to be decided with respect to the cardinal directions. According to that, the building form has to be developed, seeing in which direction the longer side of the building would be facing.

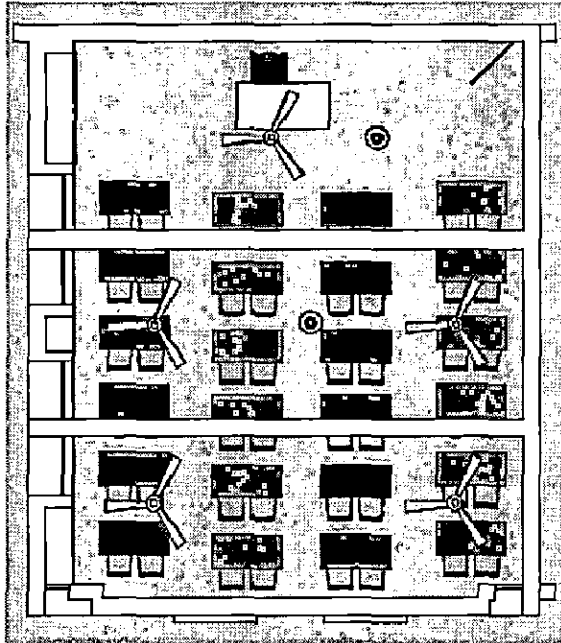
Usually schools have typical floor plans and classroom plans. These are in most cases, derived from a grid system. The inner surfaces of the classrooms should be light colored but should not have glossy finish. Furniture used should not have gloss finish either.

Window position and size play an important role. It channels flow of light into the building and also affects the distribution pattern of light in the space. Fenestrations are the main areas that can be modified for lighting efficiency retrofits like providing light shelves.

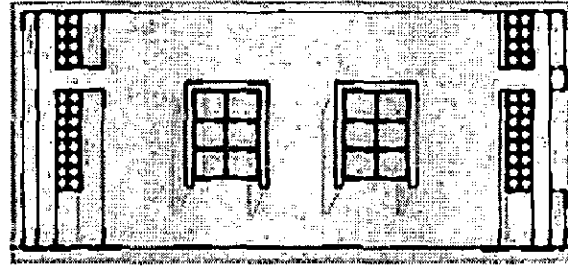
6 APPENDIX

SCHOOL 1 – ADARSH BAL NIKETAN SENIOR SECONDARY SCHOOL

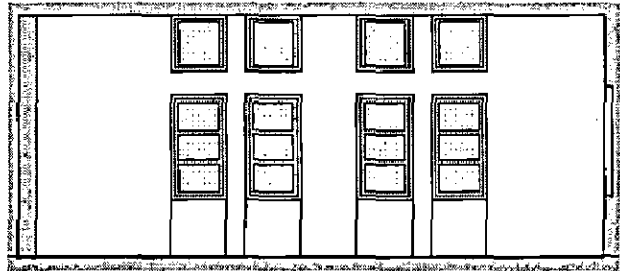
Drawings in 1:100 scale



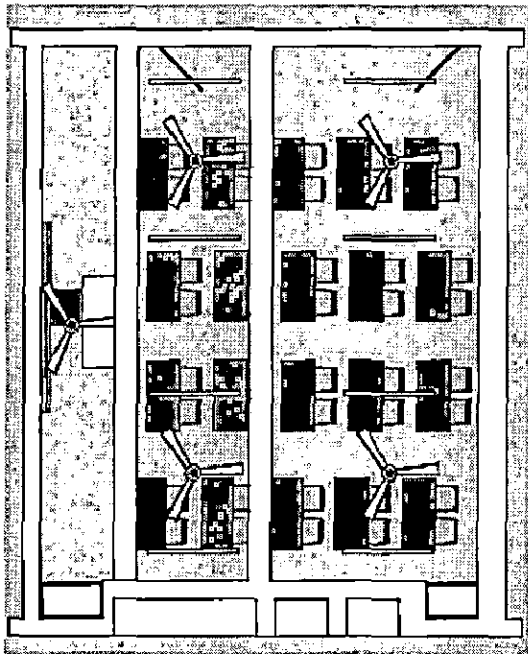
TYPICAL CLASSROOM PLAN



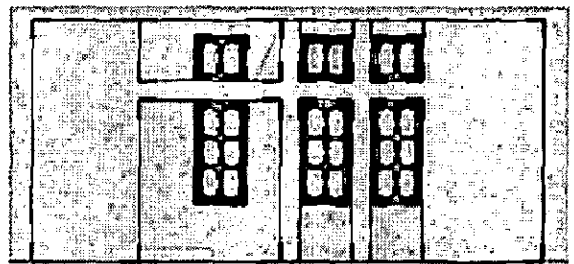
ELEVATION OF REAR WALL



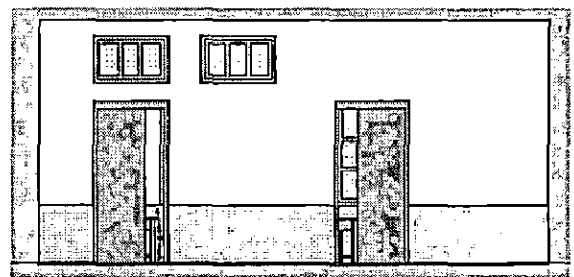
ELEVATION OF SIDE WALL



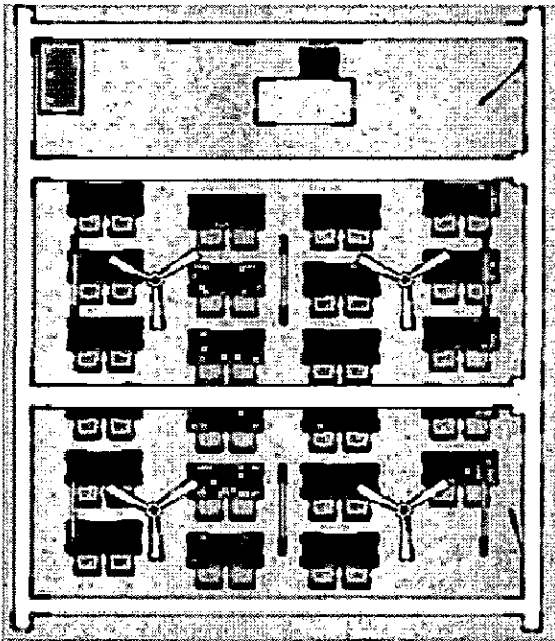
TYPE 5 CLASSROOM PLAN



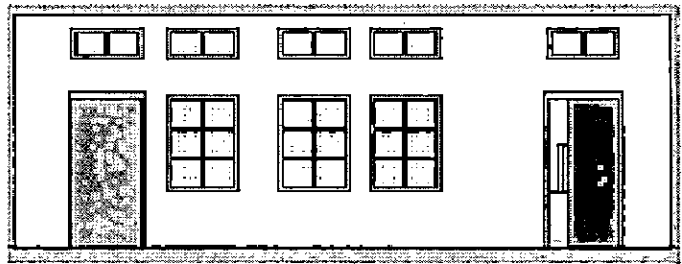
TYPE 5 CLASSROOM WINDOW ELEVATION



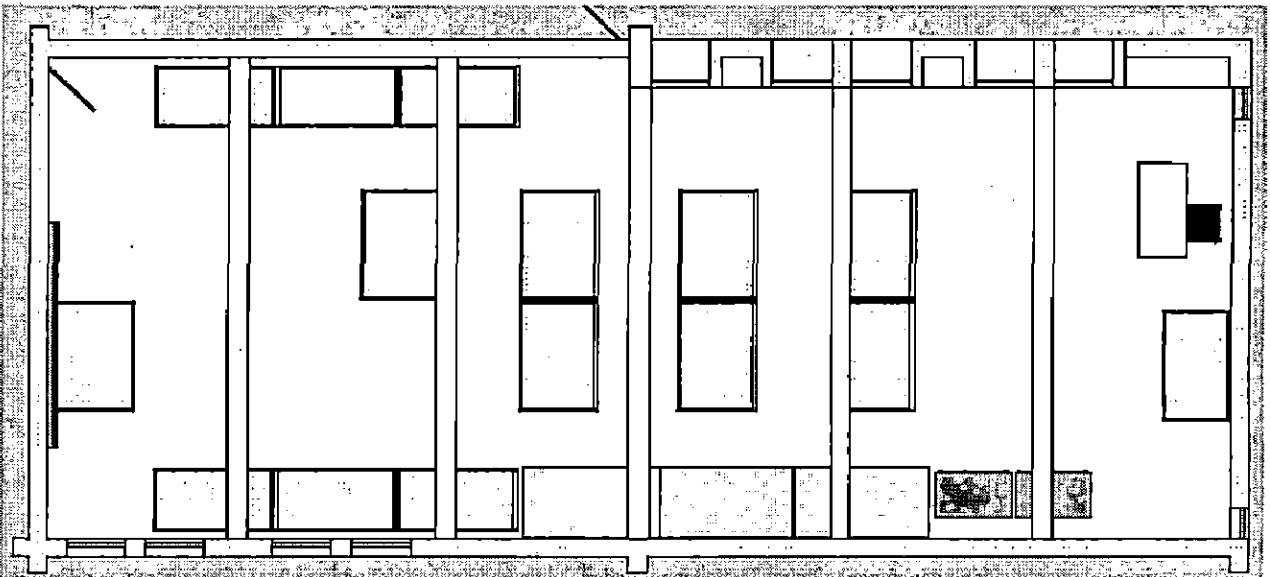
TYPE 5 CLASSROOM CORRIDOR ELEVATION



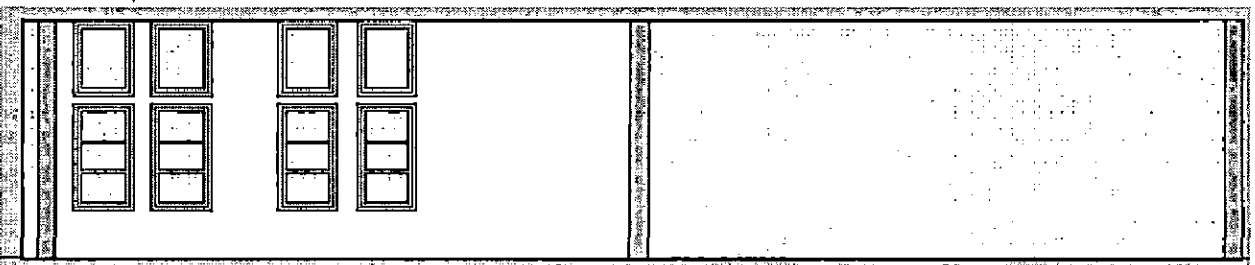
TYPE 6 CLASSROOM PLAN



TYPE 6 CLASSROOM CORRIDOR ELEVATION



LABORATORY PLAN



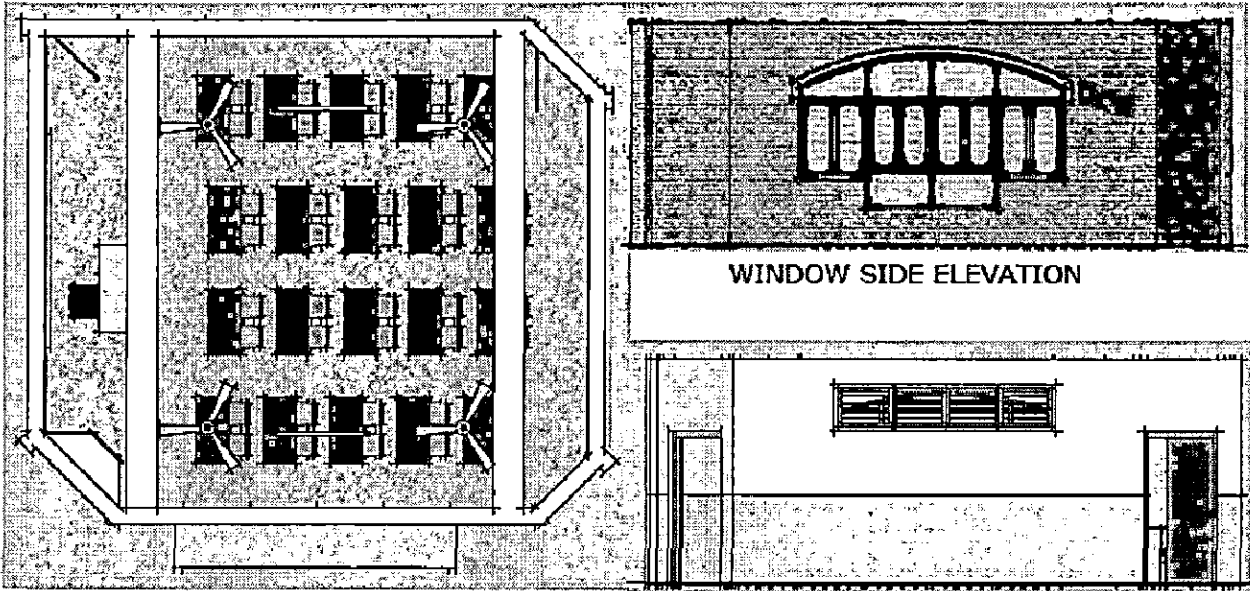
WINDOW SIDE ELEVATION



OPPOSITE WINDOW SIDE ELEVATION

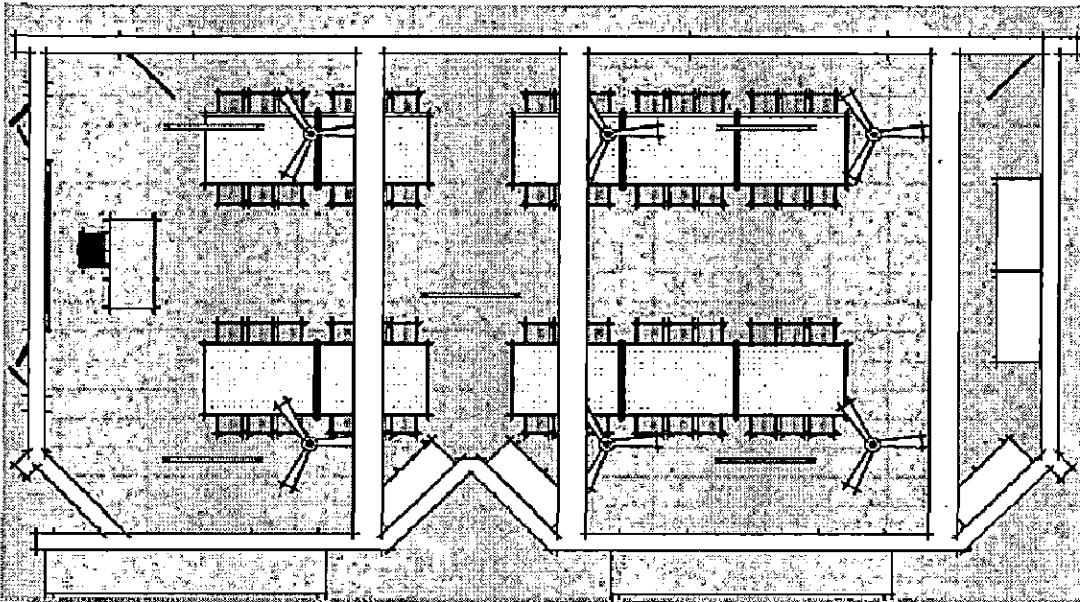
SCHOOL 2 – FATHER AGNEL SCHOOL NOIDA

Drawings in 1:100 scale

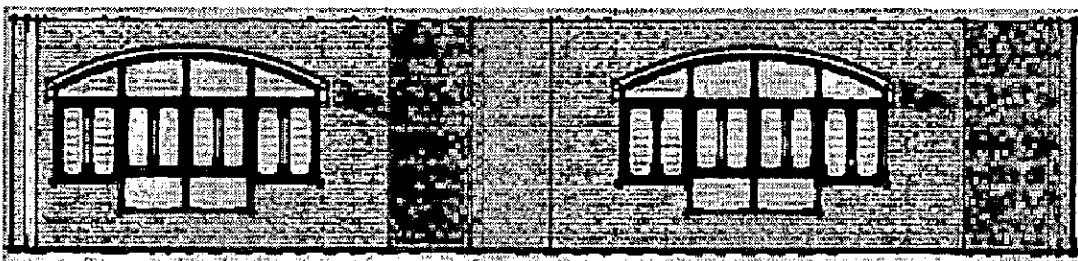


TYPICAL CLASSROOM PLAN

CORRIDOR SIDE ELEVATION



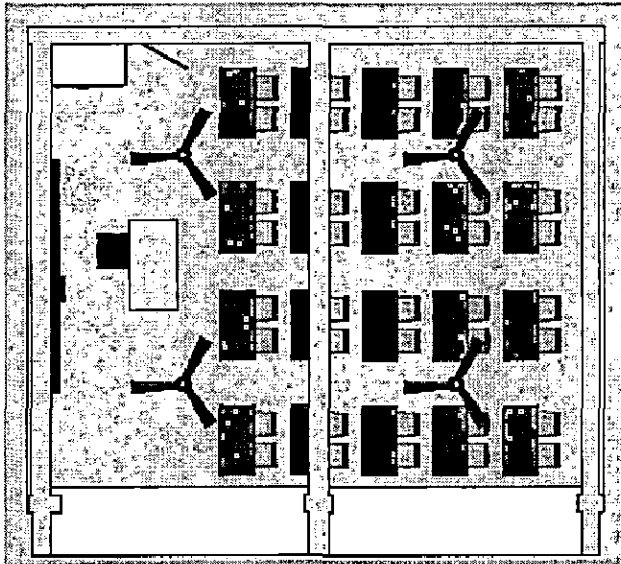
TYPICAL LABORATORY PLAN



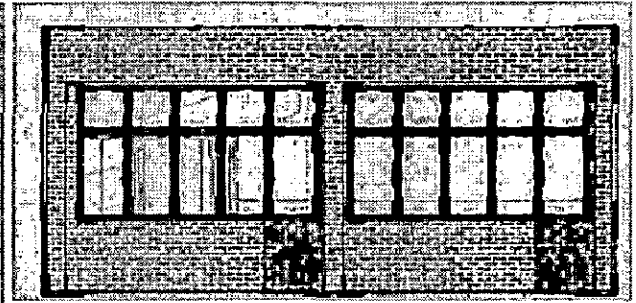
WINDOW SIDE ELEVATION

SCHOOL 3 – FATHER AGNEL SCHOOL NEW DELHI

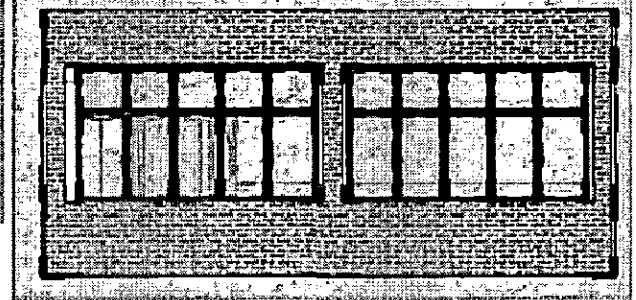
Drawings in 1:100 scale



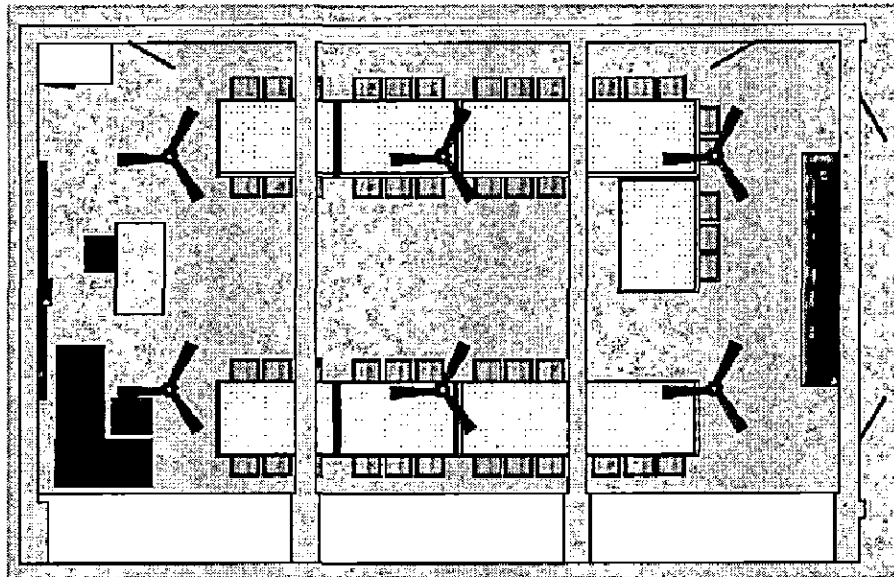
TYPICAL CLASSROOM PLAN



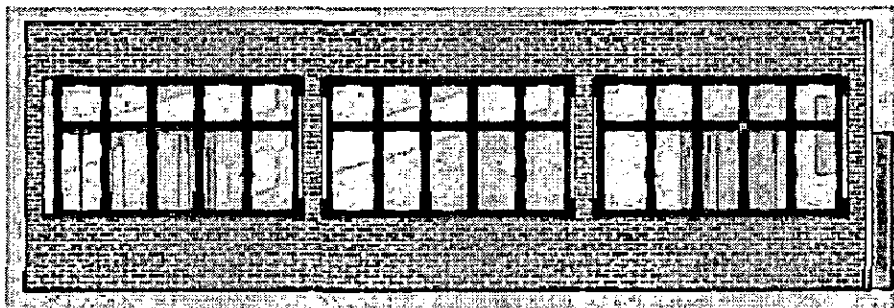
WINDOW SIDE ELEVATION GROUND FLOOR



WINDOW SIDE ELEVATION UPPER FLOOR



TYPICAL LABORATORY PLAN

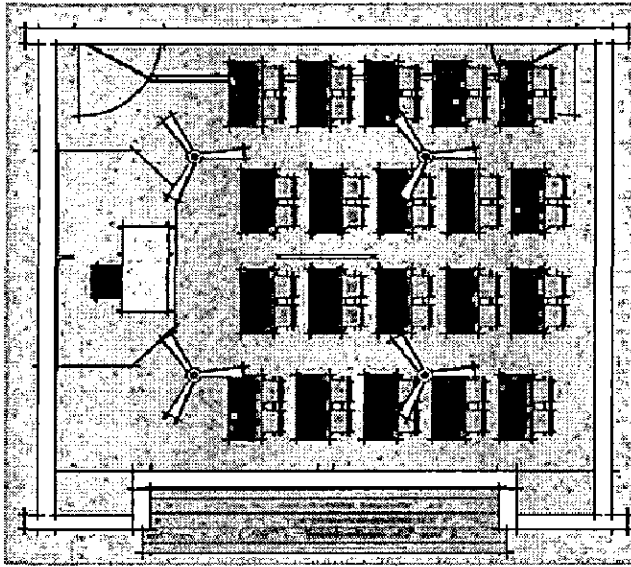


WINDOW SIDE ELEVATION

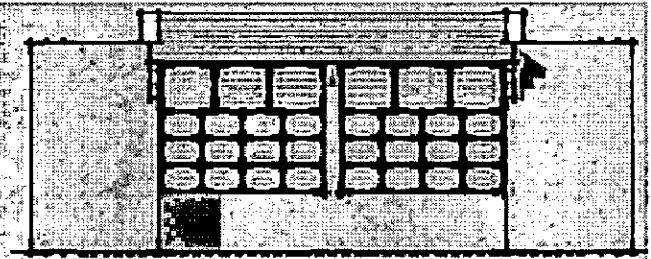


**SCHOOL 4 – KERALA SCHOOL NEW DELHI**

Drawings in 1:100 scale



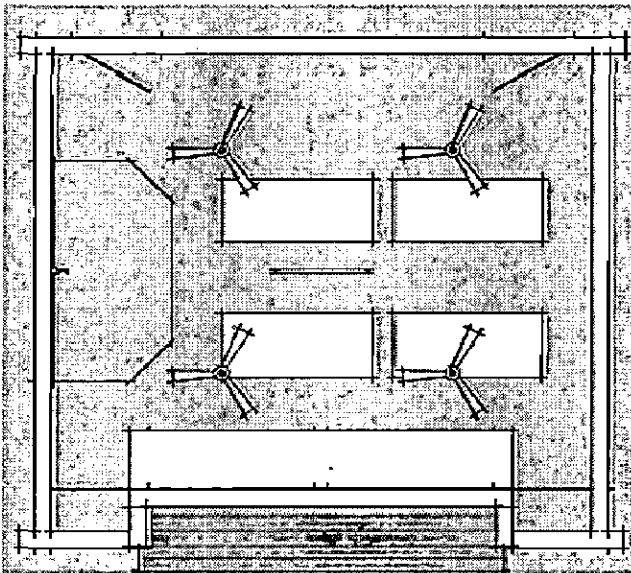
TYPICAL CLASSROOM PLAN



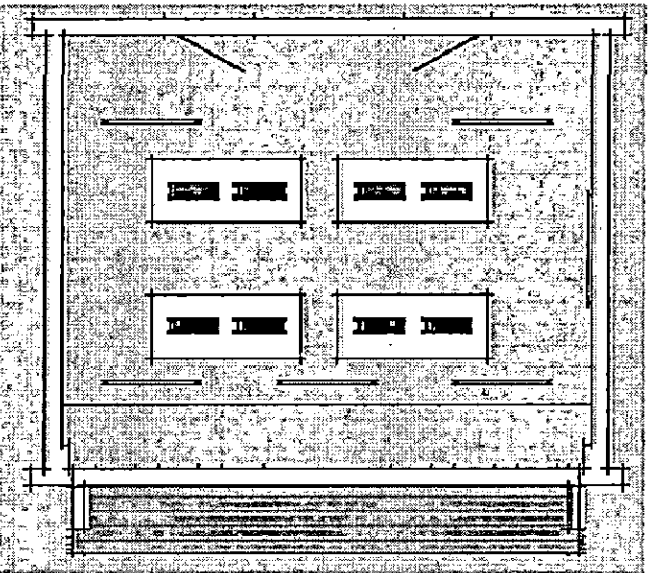
WINDOW SIDE ELEVATION FOR TYPICAL CLASSROOM AND LABORATORY 1



WINDOW SIDE ELEVATION FOR LABORATORY 2



LABORATORY 1 PLAN



LABORATORY 2 PLAN

## **7 BIBLIOGRAPHY**

### **BOOKS -**

1. William, M. C. Lam: Perception and Lighting as Form givers for Architecture
2. Hopkinson, R. G. (1970); The Ergonomics of Lighting
3. Phillips, Derek (2000); Lighting Modern buildings
4. Gordon, Gary (2002); Interior Lighting for Designers
5. Phillips, Derek (2004); Daylighting: Natural Light in Architecture
6. van Santen, Christa (2006); Light Zone City
7. GIA Lighting; Natural light works, Environmental & Daylight Design
8. BEE; Guidebook for Energy Management in Your School

### **INTERNET SOURCES –**

1. Cook, G.K (1990); Artificial Lighting in Classrooms Results of a Lighting Survey,
2. Saxena, B. K. et.al Bansal, G. D (1978); Sky Component Grids for Glazed Vertical Windows,
3. Winterbottom, Mark et.al Wilkins, Arnold (2009); Lighting and discomfort in the classroom,
4. Passive Solar Schools in UK, D. J. Harris et.al S. D. Probert, I. Nwokonkor
5. A Simplified Method to estimate energy savings of artificial lighting use from daylighting, Moncef Krarti et.al Paul M. Erickson, Timothy C. Hillman
6. Tzempelikos, Athanassios et.al Atheinitis, Andreas K; The Impact of Shading Design and Control on Building cooling and lighting demand
7. Li, Danny H. W. et.al Wong, S. L; Daylighting and energy implications due to shading effects from nearby buildings
8. Maitreya, V. K; Integrated Design for School Buildings

9. Heschong, Lisa et.al L.Wright, Roger; Okura, Stacia; Daylighting Impacts on Human Performance in Schools
10. E. Ne'eman et.al Hopkinson, R. G; Critical Minimum Acceptable Window size: A study of window design and provision of a View
11. Abdelatia, Belal et.al Marenne, Christian; Semidor, Catherine; Daylighting Strategy for Sustainable Schools: Case Study of Prototype Classrooms in Libya
12. de Mattiello, Maria L. F; Colour and light in Architecture
13. Erwine, Barbara et.al Heschong, Lisa (2002); Lighting for Learning, LD+A
14. Dean, Edward T. (2005); Daylighting Design in Libraries
15. Malman, David (2005); Lighting for Libraries
16. Ritchie, Ian (2004); Collecting Light
17. Illuminating Engineering Society (1918); Code of Lighting School Buildings,
18. [www.ridi.co.uk](http://www.ridi.co.uk); Lighting for Schools and Colleges
19. Devki Energy Consultancy (2004); Second Draft Code of Lighting
20. <http://darkwing.uoregon.edu/~akwok/VSCS/AshCreek/lighting/home2.html>, The Light In The Classroom