

Flexibility in Construction Building Structures - A Case Study

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Abstract

Buildings are generally heavy, fixed, and normally irreversible once construction has been completed. Due to changing demands of the occupants, they may confront the need for future expansion or complete changeover. Due to economic-based irreversibility, the expansion or conversion of a constructed building requires the foundation and columns to be enhanced and such options for expansion or conversion are planned at the very beginning of construction. Enhancing the foundation and columns represents an up-front cost, but has a return in flexibility for future expansion. This trade-off can be viewed as an investment problem, in that a premium has to be paid first for an option that can be exercised later. An optimum choice is required to be taken for foundations versus flexibility trade-off in order to balance the expected profits that may arise from future expansion, i.e., the value of flexibility, and the cost of enhancing the foundation. The authors in this paper explain a case of an educational institution in order to show the value of flexibility. The value of flexibility in this case study is so significant that failure to account for flexibility is not economical.

Keywords: Flexibility; Building structures; Occupant's requirement; Mathematical model; Cost and benefit of flexibility

Introduction

There is some or the other uniqueness in each construction project due to which change in the construction process is inevitable on most construction projects. Change is defined as any event or situations that results in a modification or alterations of the original scope, execution time, or cost of work [1]. Such changes occur on a project for many reasons, such as design errors, design changes, additions to the scope, or unknown conditions. Each such change has a high impact on the original cost and schedule of the project [1]. In most of the industries where there is a stable environment the changes are predictable and are not frequent. Due to which the critical variables can be identified and a plan can be developed for the same. However, in extremely turbulent and dynamic environments like construction industry where change is frequent and unpredictable, it becomes difficult to go through the routine process and follow the plan. Hence flexibility becomes inevitable for such environments [2]. The present study explores the scope of structural design characteristics of building (flexible building structure) that can make the renovation work much easy and relatively less costly. The study uses 3 major renovation cases of old educational building projects for exploring the scope of design flexibility in building structures.

Literature Review

There is a huge mismatch between what the occupant requirement is and how the building is functioning. Most of the large construction projects are planned at least 5-6 years in advance. During this time, demands on the infrastructure are likely to change significantly. Changing demands may result from new forms of construction technology, changes in government regulations, change of rules in funding agencies, etc. There are many key stakeholders who are directly linked with a construction projects like project owners, users, project management, architects, consultants, and contractors. With so many stakeholders playing a key role there is scope of frequent changes in the requirements of each stakeholder. This creates a need of flexibility in the construction projects [3]. It has been observed that a very little thought has been given on the design of flexible building structure to meet future requirement. The building developers do not want to invest for attaining future flexibility of buildings, particularly when the future requirement is not known [4]. In the present dynamic society where

the occupants requirement are changing very fast, the buildings need to be design so as to adapt to the changing needs of its occupants. It has been observed that in order to cater to the occupant's requirements, relatively young buildings (10-25 years old) are demolished. For a ready adaptation to market fluctuations it would be good to impose the condition that the building, along with its installations should be suitable for several uses [5]. This is not a desirable situation in terms of investment, waste production, energy, materials and sustainability of building [6]. There is a need to increase the functional life span of building which could be achieved if the buildings could easily be adapted to new occupant requirements [7]. It is therefore important to look at buildings from a broader perspective than just the first occupant requirements. "Flexibility can be defined as the ability to change or react with little penalty time, effort, cost or performance" [8].

Flexibility is a property of a building that is realized to some extent in all projects, even if it had not been actually taken into account in during the design phase. There are certain design characteristics of building which makes it feasible for a building for renovation work. There is a need to understand these design characteristics in order to save the future renovation cost. The projects in which there was a scope of flexibility in process, decision making, design, etc. showed higher level of success rate as compared to the projects with rigid system [9].

Method

A case study approach was used in this study to explore the scope of flexibility in design structures that makes renovation work easy. 3 major cases of renovation of old educational buildings were studied. The description of which is given below.

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Case 1

Location: Shri Ramdeobaba College of Engineering and Management, Katol Road, Nagpur.

Building Name: First year block

Literature: Shri Ramdeobaba College of Engineering and Management as established in the year 1984 with four branches of engineering at under graduate level. The intake capacity of students was 240 at first year level. The infrastructure of the college is spread at 20-25 acres of land.

The First Year block built in 1984 with G+2 floor. First Year block architectural and structural planning was carried out by considering the future vertical expansion of building. The following are the plans of the building.

Flexibility in design: There was a column beam frame structure constructed 27 years before, which proved to be supportive. So, for expansion there was no requirement for additional cost for foundation (Figures 1-4).

The first year block was built with a foresight of expansion at that time laying additional cost for making the foundations and columns strong. Thus, leaving a scope of flexibility for future expansion.

The additional floor is constructed same as the second floor hence no chance to modify the architectural parameter of the building. While going on the construction of the building all management parameter is consider by the management like safety, construction activity etc.



Figure 1: Actual photo of the first year block before vertical expansion.

The built up area of the ground floor, first floor and second floor was 561.34 Sq.mt, 561.33 Sq.mt, 561.33 Sq.mt respectively. The total built up area of the all floor is 1684.00 Sq.mt. (18133.13 Sq.ft).

The following are the proposed third floor of the building (Figure 5).

The foundation cost of the considered building (G+3) was carried out and construction of building was carried out only up to the second floor. The B/U construction cost of the building in the year 1984 was Rs. 200/- per square foot.

The cost of total built up area of the floor= $18133.31 \times 200 = 3626662.00/-$.

So, considered cost of the foundation is 20% of the total cost of the construction.

The cost for foundation and column= $3626662.00 \times (20/100) = 725332.40/-$.

(Consider additional cost is required for foundation and column for add floor as 10%).

Additional cost for foundation and column= $725332.40 \times (10/100) = 72533.24/-$.

Later in 2005 there was a need of expansion of the building by raising one more floor, this structural provision for expansion of building was already done in 1984, hence no additional treatment cost was required to the proposed third floor of the building.

The built up area of the proposed third floor is 911 Sq.mt. (9809.65 Sq.ft.) Now, the B/U construction cost of the building in the year 2005 was Rs. 1000/- per square foot.

The cost of total built up area of the third floor= $9809.65 \times 1000 = 9809650.00/-$.

Case 2

Location: Shri Ramdeobaba College of Engineering and Management, Katol Road, Nagpur.

Building name: EN/IND – BLOCK

Literature: The EN/IND block built in 1984 with G+2 floor. The EN/IND block architectural planning was not carried out by

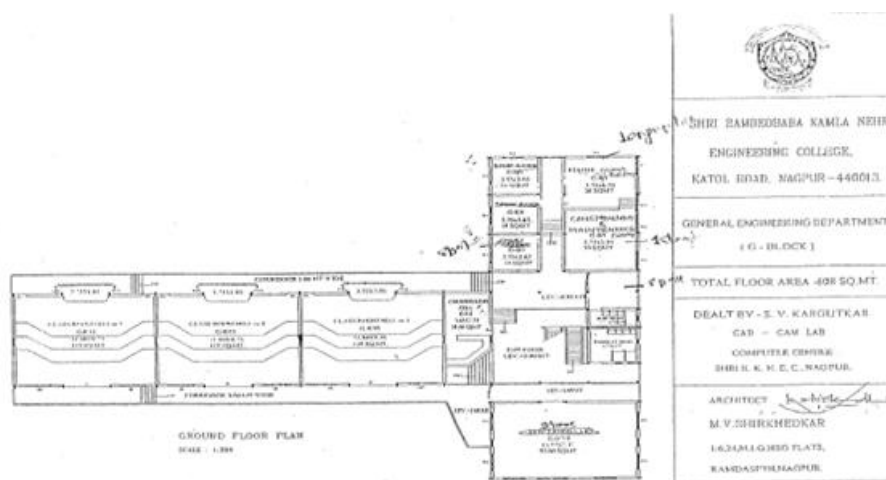


Figure 2: Ground floor plan.

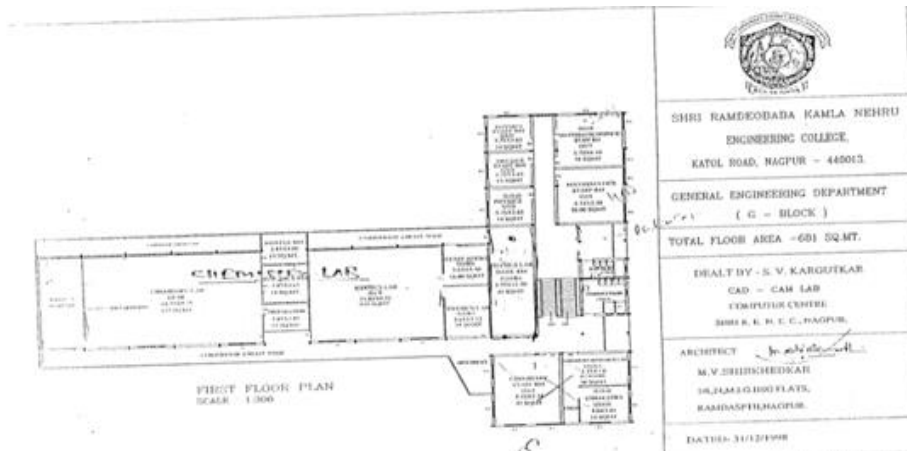


Figure 3: First floor plan.

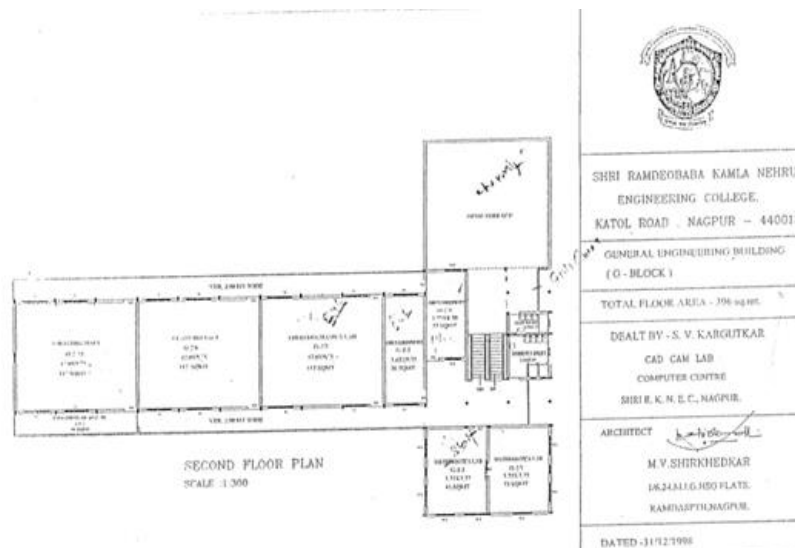


Figure 4: Second floor plan.

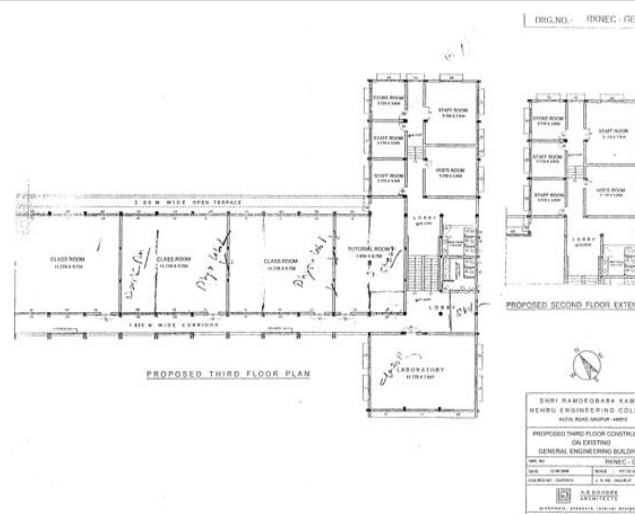


Figure 5: Proposed third floor plan.

considering the future vertical expansion of building. The following are the plans of the building.

Flexibility in design: There was a column beam frame structure constructed 27 years before, which proved to be supportive. For additional floor it was required to give the additional treatment support of column from outer periphery of the building wherever necessary as consulted by the structural engineer hence additional cost was required to make this strategy (Figures 6-9).

The additional floor is constructed same as the second floor hence no chance to modify the architectural parameter of the building. While going on the construction of the building all management parameter is consider by the management like safety, construction activity etc.

The built up area of the ground floor, first floor and second floor was 832 Sq.mt, 804 Sq.mt, 633 Sq.mt respectively. The total built up area of the all floor is 2269 Sq.mt. (24432.69 Sq.ft).

The following is the proposed third floor of the building (Figure 10).

The foundation cost of the considered building (G+2) was carried out only up to the second floor. The B/U construction cost of the building in the year 1984 was Rs. 200/- per square foot.

The cost of total built up area of the floor= $24432.69 \times 200 = 4886518.00/-$.

Later in 2005 there was a need of expansion of the building by raising one more floor but since there was no structural provision of expansion the building, additional column extra treatment was required to the proposed third floor of the building.

The built up area of the proposed third floor is 890 Sq.mt. (9576.40 sq.feet) Now, the B/U construction cost of the building in the year 2005 was Rs. 1000/- per square foot.

The cost of total built up area of the third floor= $9576.40 \times 1000 = 9576400.00/-$.

The treatment cost for making columns strong to support extra third floor= $1950000.00/-$.



Figure 6: Actual photo of the EN/IND block before vertical expansion.

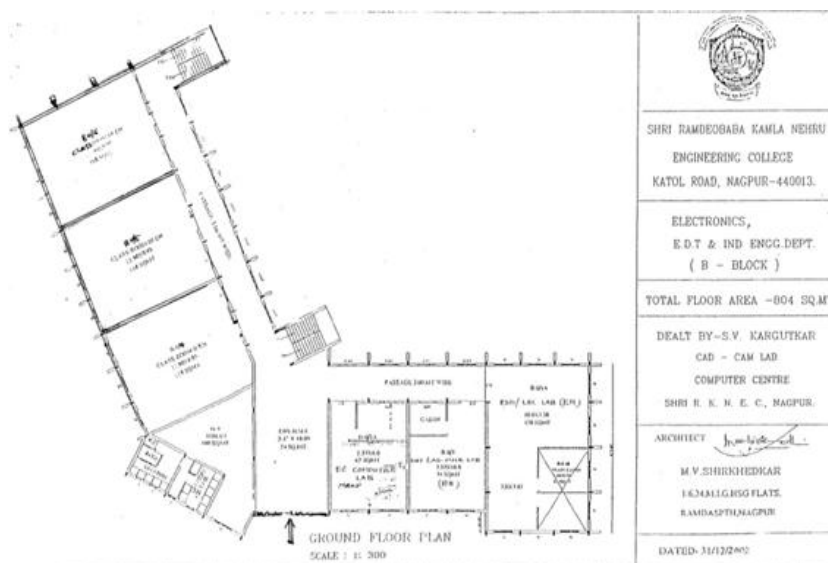


Figure 7: Ground floor plan.



Figure 8: First floor plan.

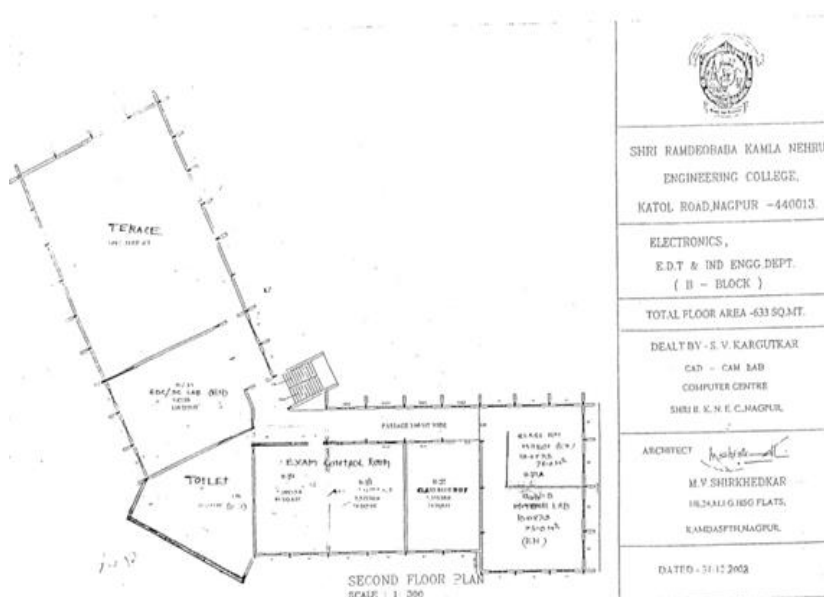


Figure 9: Second floor plan.

The total construction cost = $9576400 + 1950000 = 11526400$.

Case 3

Location: Shri Ramdeobaba College of Engineering and Management, Katol Road, Nagpur.

Building name: Civil dept. block.

Literature: The Civil block built in 1984 with G+2 floor. Civil block architectural and structural planning was carried out by considering the future vertical expansion of building. Hence additional foundation cost was laid in the year 1984 but construction was carried only up to second floor. The following are the plans of the building.

Flexibility in design: There was a column beam frame structure

constructed 27 years before, which proved to be supportive for additional floor (Figures 11-14).

The civil block was built with a foresight of expansion at that time laying additional cost for making the foundations and columns. Thus, leaving a scope of flexibility for future expansion.

The built up area of the ground floor, first floor and second floor was 440.00 Sq.mt, 440.00 Sq.mt, 440.00 Sq.mt respectively. The total built up area of the all floor is 1320.00 Sq.mt. (14213.76 Sq.ft).

The foundation cost of the considered building (G+3) was carried out and construction of building was carried out only up to the second floor. The B/U construction cost of the building in the year 1984 was Rs. 200/- per square foot.

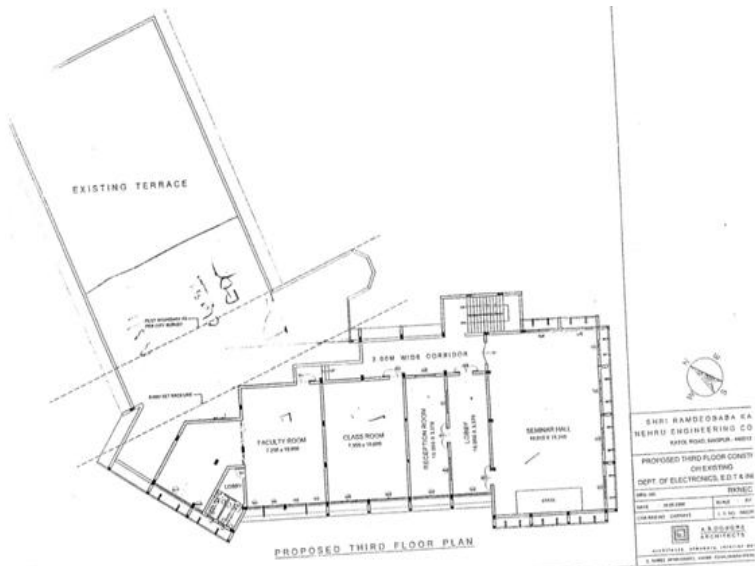


Figure 10: Proposed third floor plan.



Figure 11: Actual photo of the civil block before vertical expansion.

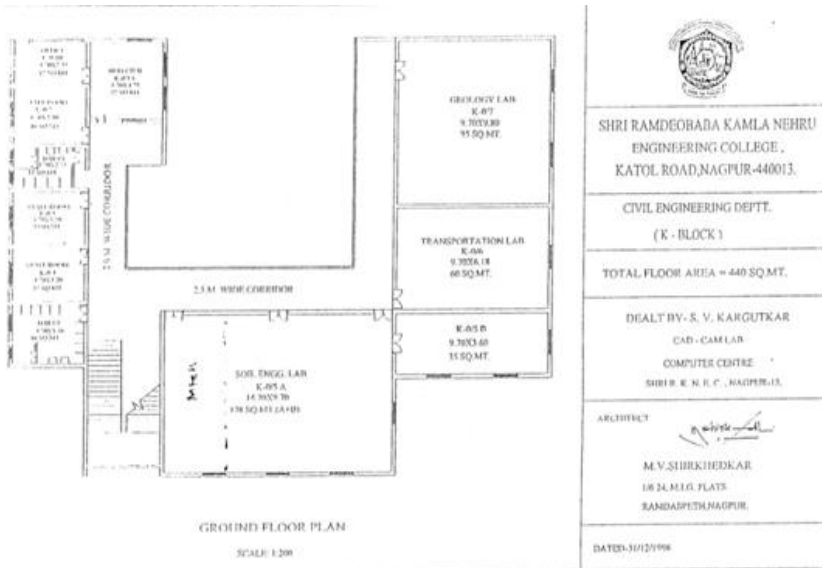
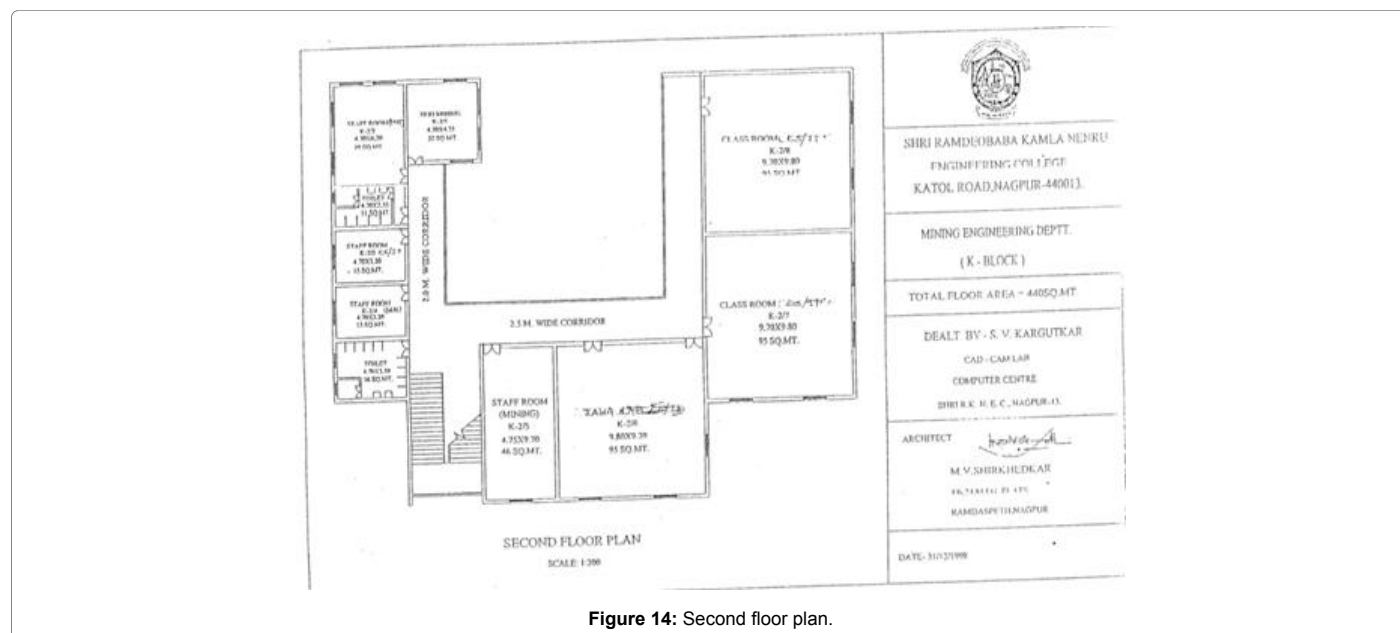
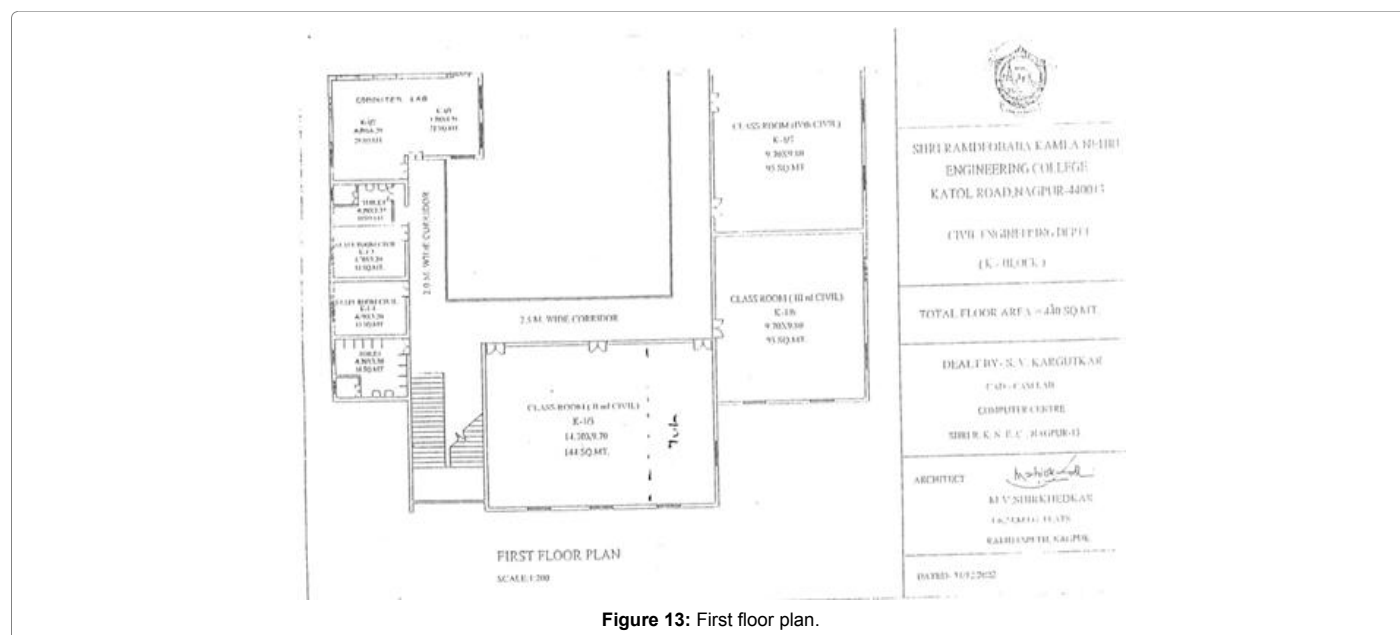


Figure 12: Ground floor plan.



The cost of total built up area of the floor = $14213.76 \times 200 = 2842752.00/-$.

So, consider cost of the foundation is 20% of the total cost of the construction.

The cost for foundation and column = $2842752.00 \times (20/100) = 568550.40/-$.

(Consider additional cost required for foundation and column for add floor as 10%).

Additional cost for foundation and column = $568550.40 \times (10/100) = 56855.04/-$.

Later, there was no requirement for the expansion of the building till date.

Case Interpretation

The careful analysis of the three cases shows that:

Case 1

The additional investment for expansion was done in 1984 of Rs. 72533.24/- which proved to be beneficial at the time of expansion in 2005 with no additional treatment cost required.

Case 2

There was no scope left for expansion at the time of initial construction and hence the treatment cost required for expansion was Rs. 1950000/-.

Case 3

The additional investment for expansion was done in 1984 of Rs. 56855/- but no expansion is done till date.

After a careful analysis of the three major cases it was observed that it is much beneficial to leave a scope of expansion or change by investing additional cost at the time of initial construction rather than incurring heavy treatment cost later. Even though no expansion is required later the additional investment is negligible as compared to the heavy treatment cost.

Result and Conclusion

The extra investment done to leave the scope of flexibility for building is much lower than the cost of expansion in case of building where there was no scope for expansion.

Bringing flexibility in projects involves costs as well as benefits. The cost of applying flexibility is much lower as compared to cost of managing unexpected changes. Hence it is better to make arrangements for flexible approach rather than dealing with changes on time. For having a proper flexible management it is necessary to identify the parts of the project where flexibility can be applied with little or no penalty costs on projects. While some researchers consider that bringing flexibility in projects will increase costs, cause delays of projects and thus will hamper the efficiency of projects, but looking at the long term goals, flexibility can be seen as adding value to the

projects by improving on the overall effectiveness of projects and customer satisfaction.

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