Application of Geographical Information System in Progress Monitoring of Construction Project

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ABSTRACT - Construction is a major sector of civil engineering. The construction industry is the second largest industry of the country and makes a significant contribution to the national economy and provides a measure of infrastructure development. Construction of vast projects such as township, stadiums, and dams is a challenging task both in terms of managing complexities of the project and addressing the demands of all the stakeholders. The success or failure of any project largely depends on the cost effectiveness, time-bound delivery, quality and amount of resources available throughout the lifecycle of construction. This clearly turns the focus towards effective construction project management. With the advances in information technologies, its use is being constantly explored in the area of construction planning and monitoring.This paper presents the concept of integrating Geographic Information System (GIS) with construction project management to provide a better solution for monitoring the progress of a project. GIS is an IT tool which with input is able to display 3-D view of building. With time as fourth dimension, the progress of construction task can be displayed as 4-D view. For the purpose of presenting the integrated GIS solution for progress monitoring, a sample three-bed room apartment is considered. The architectural drawings are prepared using AutoCAD in which the components of the buildings are distinguished into different layers. The schedule and progress of task is captured using MS Project 2003. The AutoCAD drawings are imported and digitized into shape files using ArcMap module of ArcGIS software. The 3D view representing the progress of building construction is the developed using ArcScene module of ArcGIS. The extrusions of 3D view of building depend on the progress information updated in the schedule worksheet of MS Project. The 4D model of progress monitoring is beneficial to all the stakeholders of the project and can be opted as future of planning and monitoring in the fast developing construction industry.

Keywords: Construction, Geographic Information System, GIS, Project Management

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1.0 Introduction:

Construction can be deemed as the most vital driving force for a country. It is in fact the second largest industry of India, contributing majorly to the national economy and developing the infrastructure. Construction of vast projects such as high-rise buildings, stadiums, and dams requires management of resources present in large proportions. The success or failure of any project largely depends on the cost effectiveness, time-bound delivery, quality and amount of resources available throughout the lifecycle of construction. This brings about a need for effective and efficient management; management of material, manpower, data and time. During the construction of any project, there is a huge amount of data that is collected and requires proper handling so as to provide just-in-time access in the required format. Also, the presentation of data may have to be done in different forms based on the stakeholder and the requirement. This leads to complexity in storing, manipulating, maintaining and upgrading of collected data. Geographical Information System (GIS) provides for a centralized storage of data, which can be accessed by the users anytime and anywhere and analyzed and presented in the desired format. Also, this data repository would help engineers to communicate the geospatial data, maintain current data, allow iterative design and data collection procedures without exchanging data files of different format, version and content. This helps in saving time and resources and provides better client satisfaction.

The construction industries strive for being on schedule, and cater to the needs of the population. To deliver the project on time, they need to be very fast, track information as and when required, manage the labor and also minimize wastage. The GIS application helps to achieve all such requirements with ease while acting as a central data system for all the data. Since the data can be used and integrated universally, it will allow future surveys or constructions' data to be merged with the existing ones, which in turn acts as a reference system. Therefore, the process of fabrication of a new infrastructure in a GIS would be much more efficient throughout the engineering process and can supply a serviceable management system that could cost a lot more otherwise.

Geographic Information System, referred to as GIS, can be defined as a set of tools for storing and retrieving at will, transforming and displaying spatial data from the real world for a particular set of purposes (Burrough, 1986). The ability of GIS to handle spatial data makes it a special category of

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information system. A GIS consists of four components, computer hardware, software, geographic data, and person and is designed to effectively capture, store, retrieve, update, manipulate, analyze, and display all forms of geographically referenced information.

The GIS has already gained momentum in India. During the 15th Census of India, Census 2011; GIS based thematic maps were produced for various information like Demography, Economic Activity, Housing, Urbanization etc., which allowed the data collected to be error free. The Karnataka State Natural Disaster Monitoring Centre (KSNDMC) decided to adopt the ArcGIS Server technology to power their GIS portal for Disaster Monitoring. As the real-time collection, modeling and dissemination of disaster related information is of utmost importance, KSNDMC decided to establish a Web-GIS based Disaster Monitoring portal. Municipal Corporation of Greater Mumbai (MCGM), the primary agency for urban governance in Mumbai, India, has selected ESRI ArcGIS Server technology as its citywide geographic information system (GIS) enterprise management solution. ArcGIS Server will integrate images, detailed maps, and property-level maps and link them to a wide range of enterprise data used for various city functions.

1.1 GIS in Construction Industry

GIS is being used for various purposes in construction industry. Toprakli et al. indicated the effectiveness of GIS for construction management. Bansal et al. have discussed about the capabilities of GIS to store huge data in digital format, which can be then utilized in decision making and planning of construction project. He also argued that the by using GIS based management, rework can be avoided up to 20% for time. Vijay et al. presented the use of GIS in construction management.

The potential application of GIS technology in the Indian construction site layout can be phenomenal. In India, GIS based National Highways Information System (NHIS) was developed at CSIR-CRRI for Ministry of Road Transport and Highways for about 50,000 km of National highways Data. This was done on web based GIS integrated application to view and analyze the road related data for achieving better maintenance management strategies. GIS application was also employed at Lavasa, Maharashtra for site selection of cellular towers.

1.2 Problem Statement

This paper aims to provide reasons for the inculcation of GIS in the Indian construction industry to facilitate the speed and accuracy of work with the help of 4-dimensional models of construction work. It presents the concept of integrating GIS with construction project management to provide a better solution to progress monitoring task of the project and understand the delay in the work, if any.

2.0 Methodology

A residential building is taken as an input for analyzing the effectiveness of GIS technology in construction project management. To create 4D model of construction project, three software have been used; AutoCAD, MS Project and ArcGIS. AutoCAD is used to create different layers of the construction work (Footing, Column, Walls, Windows and Doors). These layers are imported using ArcGIS software for creating 3D models. MS Project is used for creating and updating a project schedule, which defines the progress of the building. This forms an input for presenting 4D model of construction project in ArcScene which can then be used to compare the progress of work against the planned output.

2.1 AutoCAD Drawings

For reference, a drawing was prepared for a three-bedroom apartment consisting of three toilets, kitchen, living room and a dining room. The drawing consists of various components like wall, column, door and window; therefore separate layers were formed for all of them. The purpose of different layers is to determine how layers will represent the complete 3-dimensional view in GIS. Colour coding was used to distinguish them easily. All features of different layers were created in polygon. The various colours and their representation are shown in the Figures 1 & 2.

2.2 Project Schedule

A project schedule is essential for the making a project efficient and manageable. Project schedule requires the task to be broken down into smaller trackable events. For the ease of study, the structure is categorized into sub-structure and super-structure. Sub-structure includes footing and base concreting. Super-structure is further divided into columns, walls and slab. When the big components of a structure are broken down into various smaller components, it makes the project less complicated to deal with. Also, this would allow monitoring to be done with accuracy and ease. For the sake of simplicity of analyzing, each layer is assumed to be constructed at the same pace.MS Project is used as a scheduling tool. A base version of schedule is prepared with expected thickness/height, planned start and the finishing dates fed into the schedule for different activities. The activities are arranged according to their sequence and interrelationship. The base version was used to construct the planned 3D model of the project. A working version of the schedule was used to update the progress of work (height of construction work and date of recording the progress) on day-to-day basis. This working version was used to create the actual work-in-progress 3D model. The Figure 3 shows the Schedule Chart.

2.3 Import AutoCAD drawing to ArcGIS

The layers drawn in AUTOCAD was imported into ArcGIS and a mapping was done to ensure that feature classes (Polygons, lines or points) correspond to the activities defined earlier in MS Project schedule. Thus, the activities that belong together but are located at different positions were joined together as one “feature class”.

Figures 4 & 5 shows the different layers of the building transferred into ArcGIS.

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2.4 Display of 4-Dimensional model in ArcScene

The values for defining the third dimension of the shape files was extracted from the column corresponding to height/thickness as in MS Project. The base version of 3D model was prepared using the base version of schedule. Generation of 3-Dimensional view requires defined values for the attributes, base-height and layer-height which is extracted from MS Project schedule. The work-in-progess version of 3D model was generated by extracting the height value from working version of the schedule. This model was intersected with the base version of 3D model to view the delay in the planned task. The presentation of 3D model with respect to varying timeline gives rise to 4D model (time being the 4^{th} dimension of the model). Table 1 shows the comparative view of progress monitoring using 4D model in ArcGIS.

3.0 Results and Discussion

The construction industry requires a large number of activities, which makes the progress of work on site complex and tedious. Traditionally, the CPM schedule does not provide any information pertaining to the spatial aspects or context and complexities of the various components project. Therefore, to interpret progress information, interested parties normally look at 2 dimension drawings and conceptually associate components with related activities. Different project members may develop inconsistent interpretations of the schedule when reviewing only the CPM schedule. This causes confusion in many occasions and usually makes efficient communication among project participants difficult.

Integrating project schedule data with GIS technology presents a 4 dimensional model which can be utilized for the visualization of progress of the project at different stages and timeline. At a specific time interval, one can utilize the actual building model and the planned building model to compare the work in progress. The figures 6 and 7 show the Integrated view of the structure after the expected and actual progress was combined for the specific month.

The use of GIS immensely benefits all the stakeholders of the construction project; the client, the project manager, the site engineer and the project owner. The client, who probably cannot understand the building structure or is not well versed with drawings, can easily know the exact status of the project just by a glance at the 4D models. Also it allows the client has a 3-D view of the progress of work thus knowing where large cost has been incurred. The project manager is the one who controls the incoming and outgoing of all the resources; labour, material, transport etc. He needs to make decisions in order to save the cost and time been spent. Therefore, GIS would provide up-to date information about the progress. If the project site is big, it reduces the complexity. By the progress view, he would know the exact time when the resources are required in which location thus helping manage the cost and quantity of materials being used. This definitely reduces the time for decision-making as all information is in one system. Site engineer is in direct command of the site. He defines the requirements for the site and order the material. A 4-Dimensional view would let him order the ideal quantity of materials this reducing over-ordering of materials thus helping in reduction of wastage. Time component would allow him to know beforehand about the requirements, so he can inform the contractors before the work actually commences. Again, this helps in easy and correct decision making for procurement of funds or materials. Using 4D model, the project owner is able to monitor the progress of the project from one location, which helps in spending more time in chalking out the action plan for minimizing the delay.

As the construction industry expands, there is a greater requirement of GIS to be adopted for effective and efficient progress monitoring of construction project.

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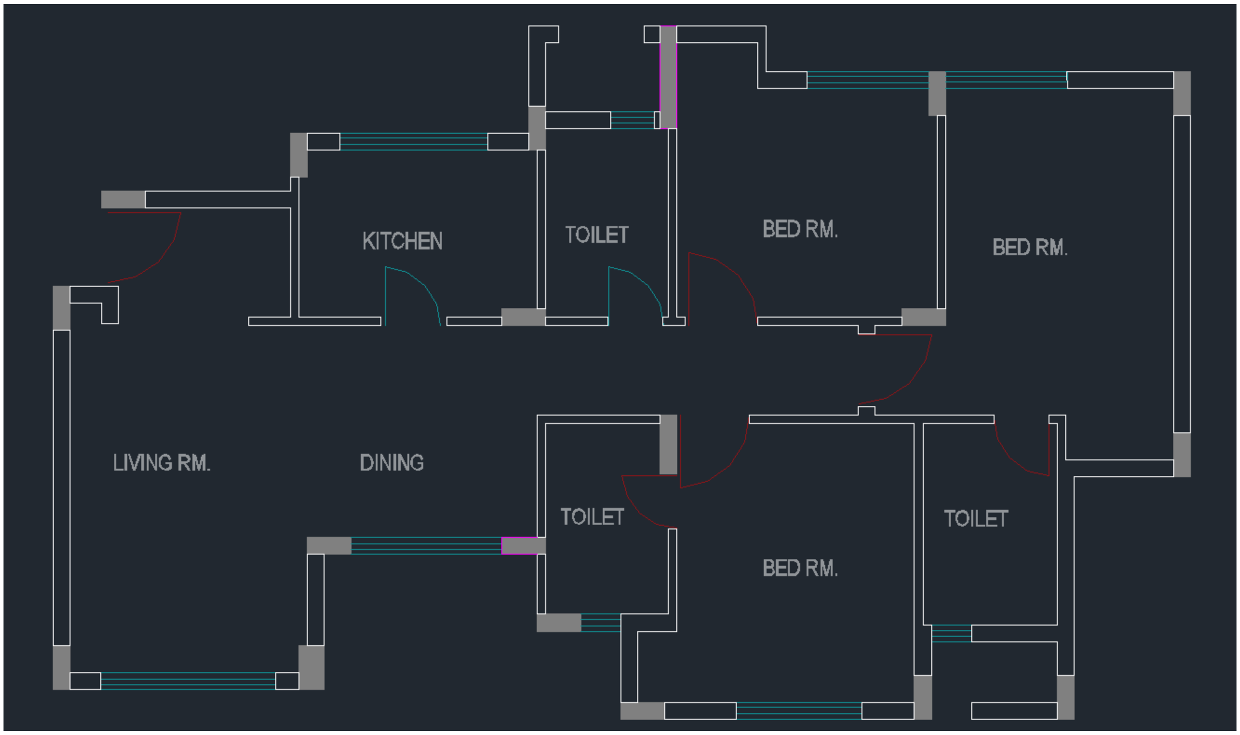

Figure 1 Complete AutoCAD Drawing

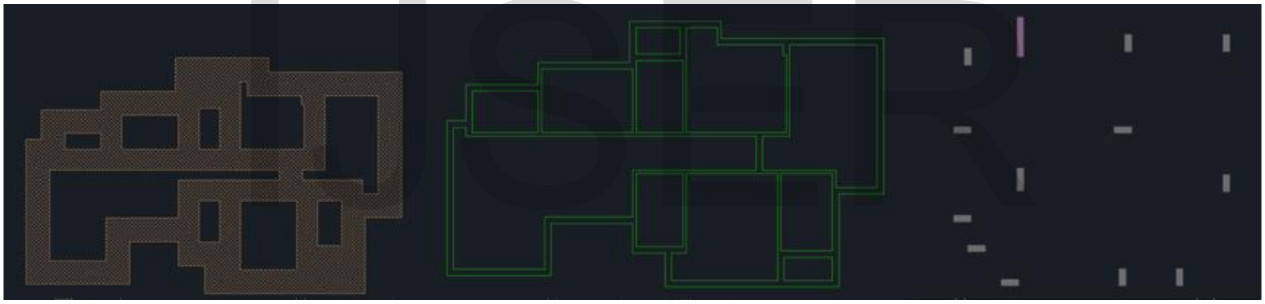

Figure 2 Layers for Footing, Wall and Columns

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Task Name	Predecessors	Duration	% Complete	Start	Finish
- Astrea		11 days?	7%	Tue 12/11/07	Tue 12/25/07
+ Mobalization of Site		1 day?	0%	Tue 12/11/07	Tue 12/11/07
- RCC Work		11 days?	7%	Tue 12/11/07	Tue 12/25/07
- SubStructure		1 day?	0%	Tue 12/11/07	Tue 12/11/07
+ Piling		1 day?	0%	Tue 12/11/07	Tue 12/11/07
+ Pile Caps		1 day?	0%	Tue 12/11/07	Tue 12/11/07
PCC Slab		1 day?	0%	Tue 12/11/07	Tue 12/11/07
- SuperStructure		11 days?	7%	Tue 12/11/07	Tue 12/25/07
- I Floor		11 days?	7%	Tue 12/11/07	Tue 12/25/07
- Type B		11 days?	7%	Tue 12/11/07	Tue 12/25/07
- PART I		10 days?	8%	Wed 12/12/07	Tue 12/25/07
+ BLDGColumn		6 days?	50%	Wed 12/12/07	Wed 12/19/07
+ Wall		6 days?	2%	Wed 12/12/07	Wed 12/19/07
+ Beam		6 days?	2%	Tue 12/18/07	Tue 12/25/07
- Slab		5 days?	4%	Tue 12/18/07	Mon 12/24/07
- S12_1	789SS,784SS,779SS	3 days?	20%	Wed 12/19/07	Fri 12/21/07
Shuttering	790SS,785SS,780SS	2 days	20%	Wed 12/19/07	Thu 12/20/07
Reinforcement Work	971SS	1 day?	20%	Wed 12/19/07	Wed 12/19/07
Concreting	972	1 day?	20%	Thu 12/20/07	Thu 12/20/07
Deshuttering	973	1 day?	20%	Fri 12/21/07	Fri 12/21/07

Figure 3 Example of MS Project Schedule

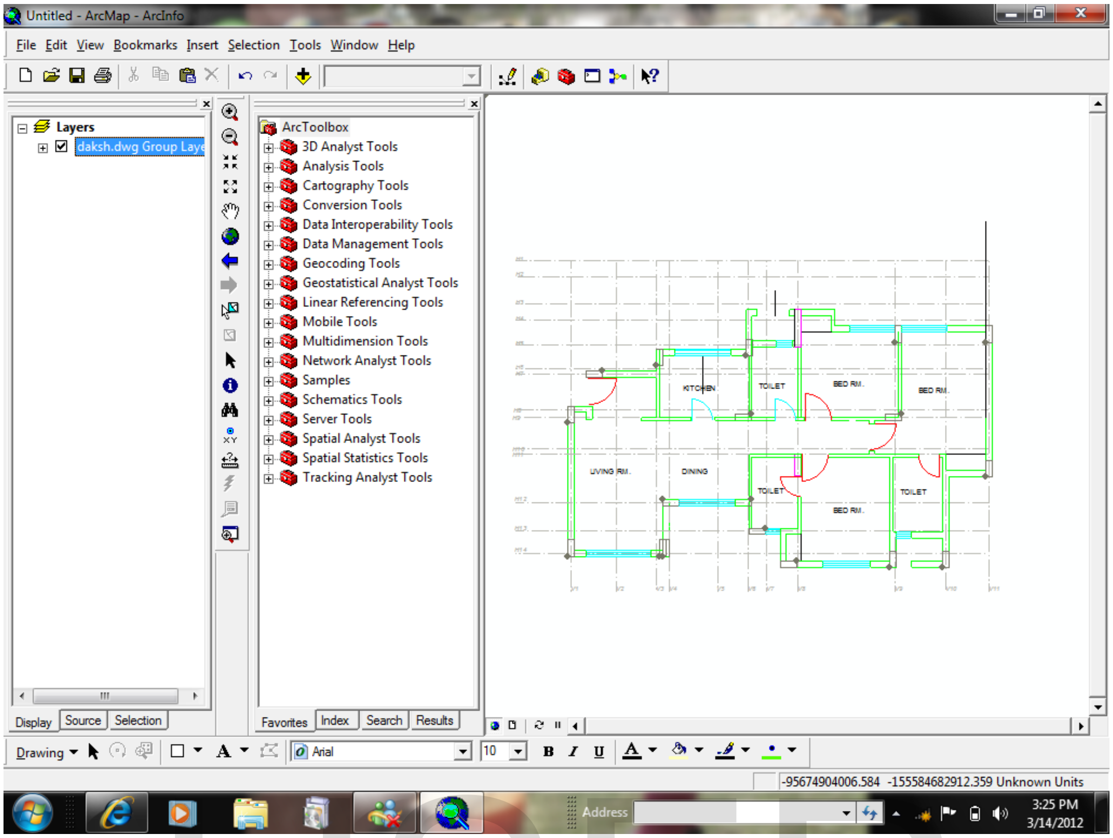


Figure 4 Import Drawing in ArcGIS

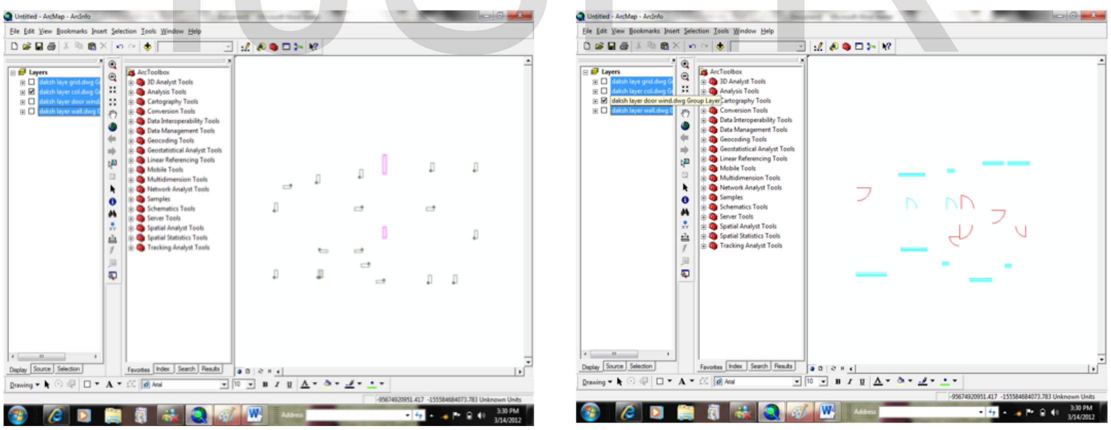


Figure 5 Layers for Column and Doors & Windows

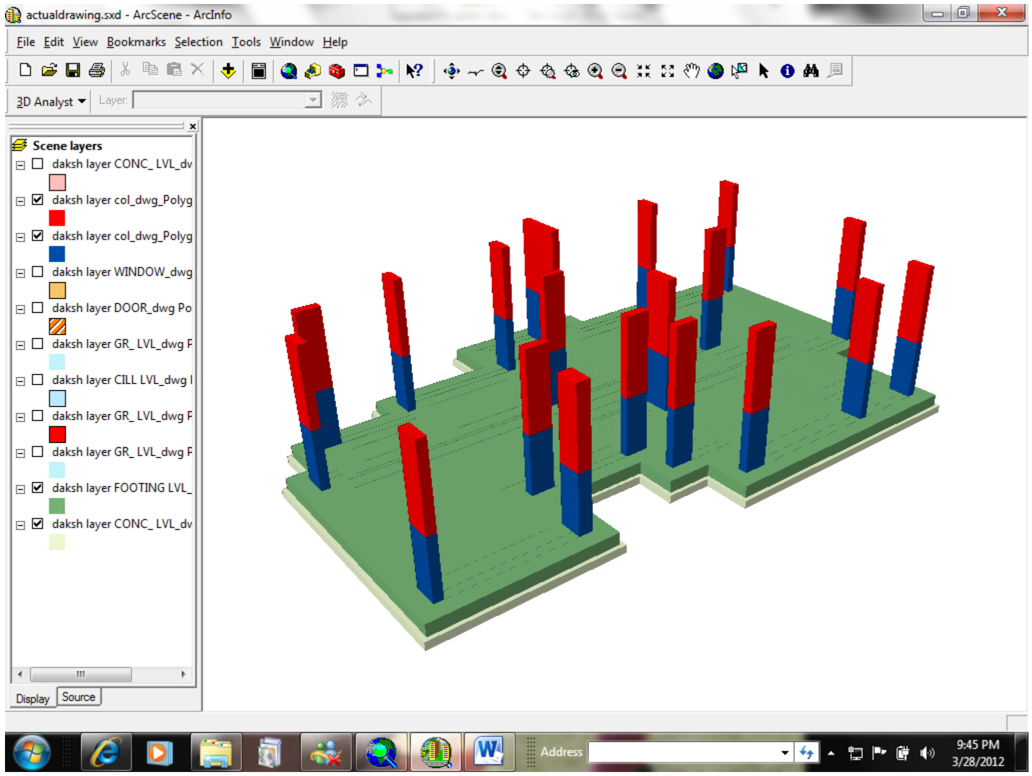


Figure 6 Second Month Delay View

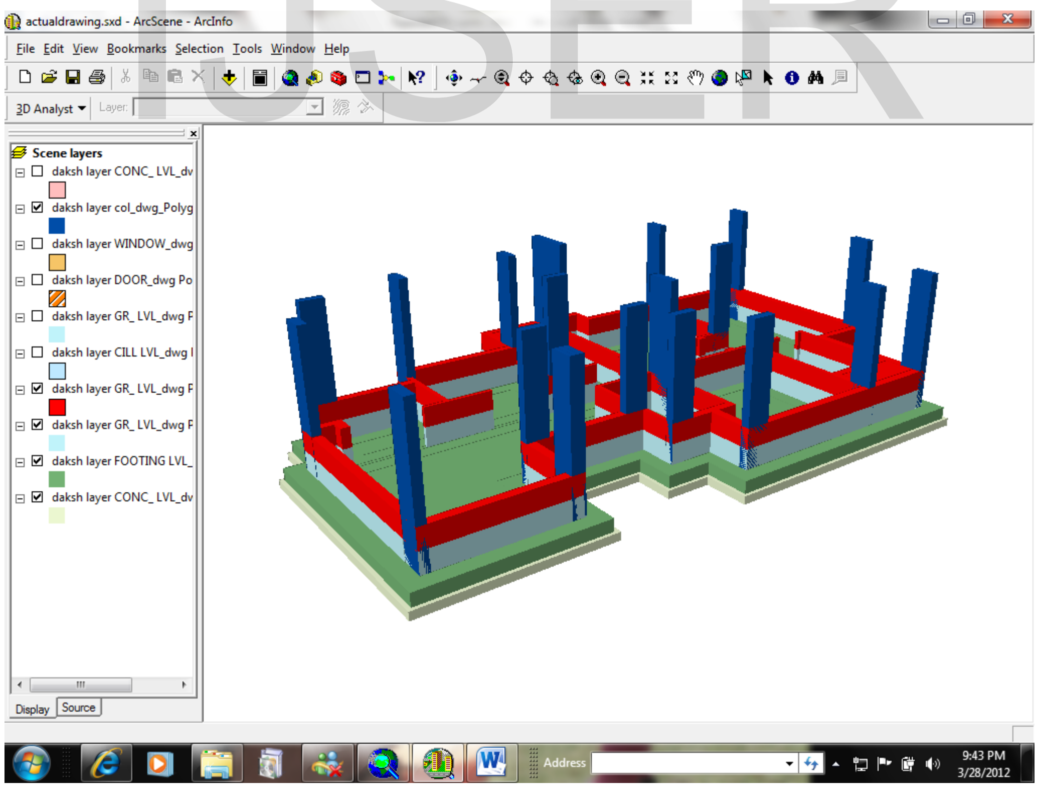


Figure 7 Third Month Delay View

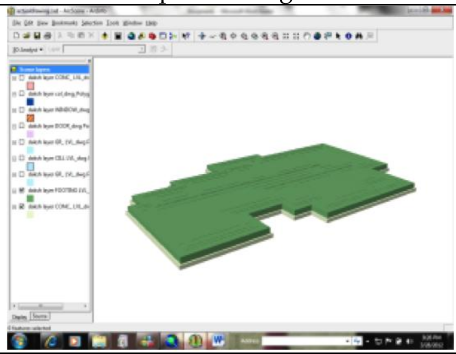
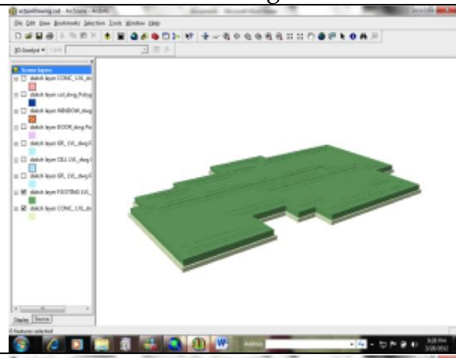
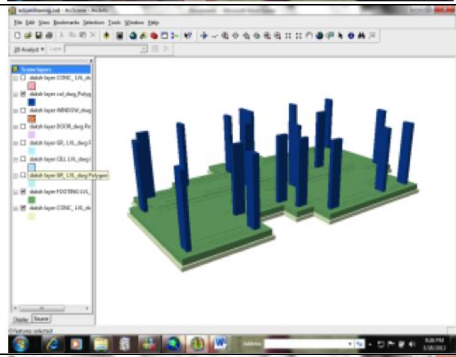
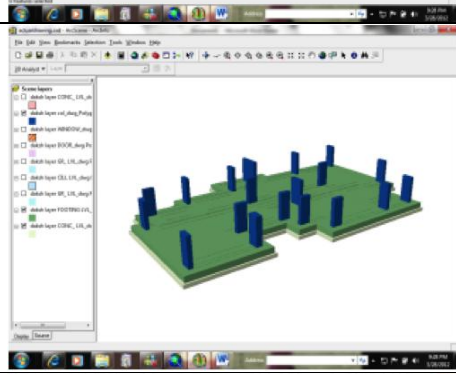
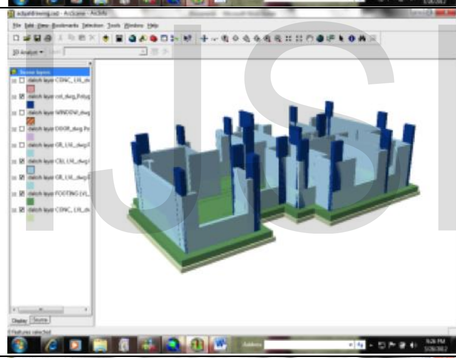
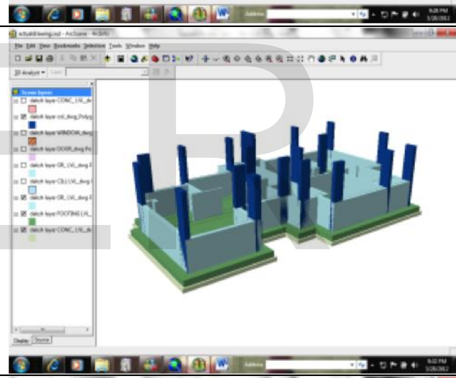
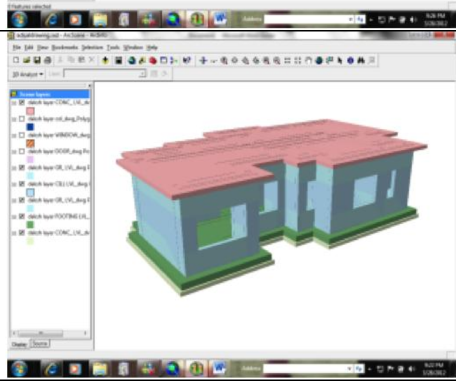
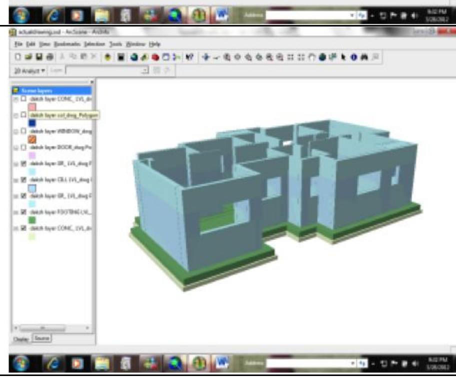
Time	Expected Progress	Actual Progress
1 Month		
2 Months		
4 Months		
6 Months		

Table 1 Comparison between Expected Progress and Actual Progress

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