

A Report focussing on:

Construction Systems and Resource Programming



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1. Executive Summary

This report aims to understand construction systems and resource programming. With the given scenario in mind, appropriate construction systems, durations and labour requirements for the different tasks will be explored. The information researched will be interpreted in a Gantt format using Microsoft Project. To conclude a justification will be made for the solutions chosen in line with the criteria given.

2. Terms of Reference

The principal focus are:

- 1.1.1.** To understand the purpose of programming using software packages for construction projects.
- 1.1.2.** Choose appropriate construction systems for the execution a multi-storey building in line with the given criteria. Establish the different activities/works required, durations of each activity and the labourers needed. Using the information collated, produce a Gantt programme for the given scenario.
- 1.1.3.** Identify and implement resource smoothing if required.
- 1.2.** The report was constrained by the information given and researched with the need to complete by 28th November 2017.

3. Procedure

This section identifies the research sources used.

- 3.1** The research included secondary sources on the subjects of construction systems and resource programming from websites and text books set out in the references and bibliography.
- 3.1** University notes also provided background to the research.

4 Findings

4.1 Programming is a key element used within the construction industry. It describes the sequence in which activities must be carried out in order for a given project to be completed on time. Programming can often identify dates, durations, critical paths, when tasks can start/finish, cost savings, where more resource is required such as laborers, plant and materials and much more. Anon. (2017). Paul Hoskins, National Planning Manager of Willmott Dixon Group states that 'An understanding of the principles of planning and programming is fundamental within any construction business and has a direct impact on its success'. Anglia Ruskin University. (2017). Many case studies found on the internet backs Paul's statement – effectively planning and managing is proven to save time and cost. Through-out this report I am going to comment on my chosen construction systems and develop a programme to reflect my choices.

4.2 Under the constraints provided, I have identified and calculated the durations for the following construction systems which are required to successfully execute the construction of a multistory commercial building;

4.2.1 **Diaphragm Wall Construction.** After some intensive research I have decided to pursue diaphragm wall for the construction of the basement. Given the location of the development and the neighboring high-rise buildings, the construction of diaphragm wall is relatively quiet and has little vibration thus providing little / no impact to the surrounding environment. In order to understand the construction time constraints for this method of construction I approached a few diaphragm wall contractors. Fortunately a company called 'Bachy Soletanche' (Bacsol) who is one of the UK's leading geotechnical specialists responded to my email which can be viewed in appendix A. (Appendix A). Ian Acreman, one of the Bid Managers at Bacsol provided me a recent case study which identified rates/durations for following tasks;

- Mobilisation
- Guide Wall Construction
- Pre-Excavation for Diaphragm Wall
- Desanding/Cleaning of Wall
- Reinforcement Cage Placement
- Concreting and Tremieing

The information supplied was used to calculate the construction time scale for the basement construction. Acreman, I. (ian.acreman@bacsol.co.uk). Calculations for this element can be found in appendix B – Diaphragm Wall Construction. (Appendix B)

Ground Anchoring was also used to support the diaphragm walls during the excavation of the basement. I identified that 2 ground anchors would be suffice per block. Rates for ground anchoring were taking from Planningplanet.com. Anon. (2009).

4.2.2 **Raft Foundation.** In order to construct the foundation of each block, I have identified the following steps;

1. Blinding
2. Drainage and Utilities
3. Steel Work Preparation
4. Concrete Pour
5. Concrete Cure Period

In order to calculate the duration required for some these tasks I used the 'Spon's Architects' and Builders Price Book 2015' which contains theoretical rates.

$$\text{Duration} = \frac{\text{Work Load X Labour Hours}}{\text{No. of Gangs}}$$

For example; In order to calculate the duration to 'blinding' each block, SPONS indicates that it takes 1.71 hours per m³. The Volume required for each block is 75m³. (500m² x 0.15m). Therefore using 1 labourer it would take 16 days (working 8 hour days) to complete (75 x 1.71). In order to reduce the duration I introduced more labourers; $\frac{75 \times 1.71}{8 \text{ Labourers}} = 2 \text{ days}$

Other sources of information were used to calculate duration of these tasks which can be viewed in Appendix B.

4.2.3 **Reinforced Concrete Superstructure.** An online article suggests that concrete is the most commonly used construction material on earth. Anon. (2016). I have chosen to construct the multistory building with concrete as the material is cheap and easy to source. It's versatile and pliable properties means that it can be easily shaped. Concrete gradually hardens over time, thus the reason for allow a curing period within my Gantt programme – 14 days. Mohan, K. (2016).

4.2.4 **Pre-Cast Concrete Cross Wall Exterior.** This technique of cladding/exterior wall construction is a much faster method than the traditional brick and block. Pre cast components are built off site and brought to site when ready for installation. This is known to raise onsite productivity and to reduce the cost labour and materials. A useful book called 'Cost Model Study – Commercial Buildings' helps understand the speed of this method of construction. With reference to the figure below, I was able to calculate the amount of time it would take to install the exterior panelling to each sub-block within my commercial building.

Figure 1 Typical Speed of Construction. Anon. (2017a).

As you can see, to install 500m² of Cross Walling, it would take 1 week using 1 crane. With reference to appendix C I have calculated that would take 7 days using 2 cranes to install enough walling for sub-block A. Please see the example below;

$$\frac{1450 \text{ (Total area required)}}{500 \text{ (Crane)}} = \text{Approx. 3 Weeks}$$

Therefore using the equation **Duration = $\frac{\text{Work Load X Labour Hours}}{\text{No. of Gangs}}$**

$$\frac{3 \text{ weeks}}{2 \text{ Cranes}} = 1.5 \text{ weeks (7days) to complete}$$

4.2.5 **Flat Roof Construction with Asphalt finish.** – I have identified the following tasks to construct the roof for the commercial building block;

1. Formwork /Shuttering
2. Concreting Roof
3. Concrete Cure Period
4. Roof Asphaltting

In order to determine the time required to carry out formwork / shuttering for an area of 500m², I approached steel fixers in my work place. They advised that this would take 5 days to complete with a gang of 4 fixers. With regards to the concreting, I used SPONS again which supplied me labour rates and finally 'Planning Planet' provided me with rates for roof asphaltting. All of these calculations can be viewed in Appendix B and C. Anon. (2009a).

4.3 Using the formulas mentioned above and with the aid of SPONS and other online resources I have produced a Gantt programme for my chosen construction methods. As the document is too large to attach to this report, I have emailed a copy to Juan Ferriz Papi on 28/11/2017. It

must be noted that the labour rates used are theoretical and that the calculations used to determine the different task durations illustrated within the Gantt programme can be found in appendix B and C. A summary of the Gantt programme can be view at appendix D

- 4.4** According to many online articles, resource smoothing is used when the projects finish date cannot be moved, this is known as a time constraint. The smoothing element makes use of the 'float', which allows you to re-allocate the resources. Holt, B. (2015).
I have identified that no resource smoothing is required within my project.

5.0**References**

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Last accessed 25th Nov 2017

6. Appendices

Appendix A – Email from 'Bachy Soletanche'

FW: Diaphragm Wall Construction

5 days ago
from ACREMAN Ian
to Matthew Evans (P148192)
cc GILLIES Stewart

Matthew

In reply to your query below:

Mobilisation of diaphragm wall plant and equipment to site and set-up: 3 weeks

Demobilisation of diaphragm wall plant and equipment from site: 2 weeks

Guide wall construction: 25-30m/shift per gang

Diaphragm Wall Panel Excavation under bentonite support fluid: 8-9m²/hr

Desanding of a diaphragm wall panel: 60m³/hr

Reinforcement cage placement: 1-1.5 hours per cage splice/joint depending on the complexity of the cage.

Placement of tremie pipes for concreting: 1-1.5 hours

Concreting: 32m³ per hour or 1 x circa 8m³ truck every 15 minutes; though this is somewhat dependent on the supplier's capability.

Removal of tremie pipes for concreting: 1-1.5 hours.

The above is for guidance purposes only and is based on:

Constructing a diaphragm wall through typical London geology consisting of say 6m of Made Ground and River Terrace Deposits overlying London Clay.

The toe level of the diaphragm wall terminating in London Clay.

Diaphragm wall panel depth circa 25m.

2 tremie positions per panel 3.6m to 7.2m in length. 1 tremie would be used for panels less than 3.6m in length and 3 tremies used for panels greater than 7.2m in length.

Good access/egress to site.

Unrestricted and sufficient working space on a level site to safely and productively operate conventional diaphragm wall plant and equipment to meet the production rates outlined above.

Diaphragm wall excavation using a hydraulic grab and associated attendant plant e.g. service cranes, excavators and Moxie type dumpers, bentonite plant, etc.

Please use the links below to access our website where you'll find information about retaining wall techniques and associated case studies.

<http://www.bacsol.co.uk/technique/retaining-walls/>

<http://www.bacsol.co.uk/case-studies/>

I wish you the best of luck with your University assignment.

Regards

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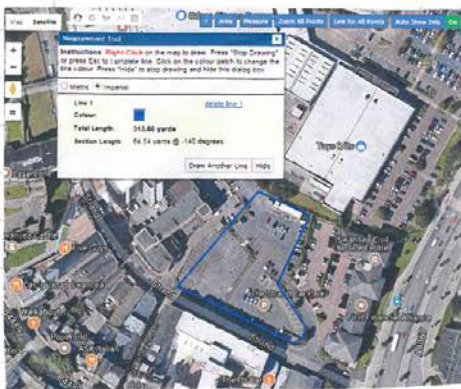


Appendix B – Construction Task / Labour Hour Research

Research - Labour Hours/Tasks

Site Mobilisation

- Secure Site with Heras Fencing
 - It has been advised by the fencing contractor at persimmon Homes that to Secure a site with Heras Fencing at this scale (Roughly 290m) will take 2 days. (16 hours). Refer to image below
- Set up Office and Welfare facilities
 - From past experience within the construction industry, this task will take 2 days (16 hours) to complete.
- Install temporary Supplies (Water + electric)
 - On a recent development in "Swansea", installation of Water (Welsh Water) and electric (WPD) took 2 days, therefore, taking a view on this, allow 2 days (16 hours) for the installation of temporary Supplies.
 - Glan Yr Afon Development, Swansea
- Material and Plant Storage
 - It has been advised by "Bachy Soletanche" that mobilisation of the plant required by a diaphragm Wall Contractor would take 3 weeks. Other plant and materials can be stored during this time. (Refer to email dated 23/11/2017 from Ian Avernham)



• Approx perimeter of site = 313 Yards
= 290m
(www.guidefinder.com)

Earth Works

• Site Clearance

- Excavating / Removal of existing car park (concrete to be assumed) = 2.55 labour hours per m^3 (SPONS, p 229)
- Approx area = $4331 m^2$
- Depth of excavation required = 150mm

$$\text{Total volume to be excavated} = 4331 \times 0.15 = 649.65 m^3$$

Therefore with 1 excavator machine, it will take 1656.6 hours to complete the task. (649.65×2.55)

• Removal of rubble debris

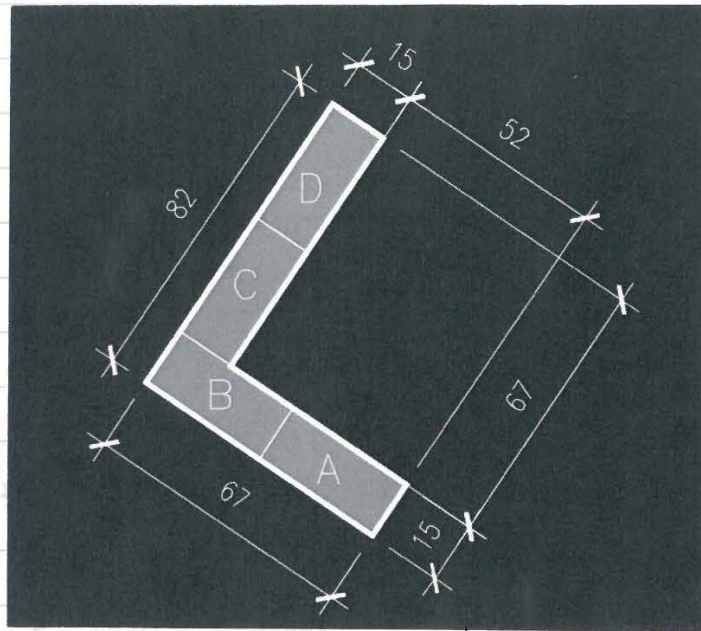
- $1 m^3$ of concrete rubble = 2.45 tonnes
- 1 Lorry can accommodate 20 tonnes
- 1 round trip from Swansea to landfill site on Fabian way is approx 40 minutes (Recent experience)

Therefore it will take 81 journeys (1 Lorry) to cart material off site.

$$\begin{aligned} 20 \div 2.45 &= 8.1 m^3 \\ \frac{649.65 m^3}{8.1 m^3} &= 80.2 \text{ journeys} \end{aligned}$$

$$\begin{aligned} \text{Therefore total time to remove} &= 81 \times 40 \text{ minutes} \\ &= 3240 \text{ minutes} \\ &= (54 \text{ hours}) \end{aligned}$$

Basement Construction - Diaphragm Wall



- Area of each block = 500m^2
- Total Area of 4 blocks = 2000m^2

Total length of diaphragm = 261m
 Depth of diaphragm wall (approx) = 8m
 Width of diaphragm wall = 1m

• Guide Wall Construction

→ 30m/Shift per gang

(Shift = 1 day = 8 hours)

$$\frac{261\text{m}}{30\text{m}} = 8.7 \text{ Shifts required}$$

• Excavation for Diaphragm Wall (under bentonite support)

→ $9\text{m}^3/\text{hour}$

→ Total volume of diaphragm wall to excavate 2088m^3
 ($261 \times 8 \times 1$)

$$\text{Total excavation duration} = \frac{2088}{9} = 232 \text{ hours}$$

• Desanding of diaphragm Wall (clearing)

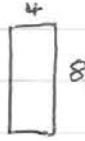
→ $60\text{m}^3/\text{hour}$

$$\text{Total duration for clearing} = \frac{2088}{60} = 34.8 \text{ hours}$$

- Reinforcement Cage Placement

→ 1.5 hours per cage splice/joint

→ Assume cages are 4 x 8



$$\frac{261}{4} = 65.25 \text{ cages required}$$

$$= 66 \text{ cages}$$

$$\frac{66}{1.5} = 44 \text{ hours}$$

- Concreting and Tremieing

→ 3m³ / hour

→ Total Volume = 2088m³

$$\frac{2088}{32} = 65.25 \text{ hours}$$

Note: Most of the above information had been supplied by "Bachy Soletanche" - please refer to email enclosed. These figures have been used/interpreted from a case study.

- Joining of Wall Sections

→ Wall Sections are assumed to be 15m in length

→ Total length of Wall = 261m

→ Assume 1 joint = 4 hours

$$\frac{261}{15} = 17.4 \text{ joints}$$

$$17.4 \times 4 \text{ hours} = 70 \text{ hours}$$

- Excavation of total Basement (Inside diaphragm wall)

16000 (Volume 2000x8) m³ x 0.12 (labour hours) = 1920 hours
(SPONS, p 228)

- Removal of Basement material
 - 1m^3 of soil is approx 1.6 tonnes (Sand clay)
 - 1 lorry can accommodate 20 tonnes
 - 1 round trip to nearest tip (Fabian way, Swansea) = 40 minutes

$$\begin{aligned}\text{Total volume of material} &= 500\text{m}^2 \times 8\text{m} = 4000\text{m}^3 \\ &4000 \times 4 \text{ (Sub-blocks)} \\ &= 16000\text{m}^3\end{aligned}$$

$$20 \div 1.6 = 12.5\text{m}^3$$

$$\frac{16000}{12.5} = 1280 \text{ journeys}$$

$$1280 \times 40 \text{ mins} = 51200 \text{ minutes}$$

$$= \text{approx } 853 \text{ hours}$$

- Ground Support - Anchoring
 - Drilling shaft (30m) = 7 hours
 - Install Anchor = 6 hours
 - Grout = 2 hours
 - Stressing = 32 hours

$$\text{Total time for 1 anchor} = 47 \text{ hours}$$

Foundations (Per Sub-block of 500m^2)

• Blinding

→ Labour hour = $1.71 / \text{m}^3$ (SPONS, p 593)

→ Volume required = 500×0.15 (depth of blinding)
 $= 75\text{m}^3$

$$75 \times 1.71 = 128.25 \text{ hours}$$

• Drainage and Utilities

→ Assume 2 days (per block) - previous experience

• Steelwork for Raft Foundation

→ Steel Mesh and reinforcement = $0.08 / \text{m}^2$

(according to www.methum.org/construction-production-rates/)

$$500\text{m}^2 \times 0.08\text{m}^2$$

$$= 40 \text{ hours}$$

• Concrete Pour for foundations

→ Labour hour = 1.02 m^3 (SPONS, p 254)

→ Assume depth = 450mm

$$\begin{aligned} \text{Volume} &= 500 \times 0.45 \\ &= 225\text{m}^3 \end{aligned}$$

$$225 \times 1.02$$

$$= 229.5 \text{ hours}$$

∴ Sub-block ^A = 5 floor

$$5 \times 290\text{m}^2 = 1450\text{m}^2 \text{ required}$$

$$\frac{1450}{500} = 2.9 \text{ half weeks}$$

$$500 = 3 \text{ half weeks}$$

Therefore to install 1450m^2 of wall using 1 crane = **1.5 weeks**

$$\text{Sub-block B} = 7 \times 290 = 2030\text{m}^2$$

$$\frac{2030}{500} = 4 \text{ half weeks}$$

∴ **2 weeks** required

$$\text{Sub-block C} = 11 \times 290\text{m}^2 = 3190\text{m}^2$$

$$\frac{3190\text{m}^2}{500\text{m}^2} = 6.5 \text{ half weeks}$$

$$\frac{6.5}{2} = \text{3.25 weeks required}$$

$$\text{Sub block D} = 15 \times 290\text{m}^2 = 4350\text{m}^2$$

$$\frac{4350}{500} = 8.7 \text{ half weeks}$$

$$\frac{8.7}{2} = \text{4.35 weeks required}$$

Note: Numbers have been rounded for simplicity



(Refer to block sketch)

$$\begin{aligned} \text{Total surface area per floor} \\ = ((33.5 \times 3) \times 2) + ((3 \times 15) \times 2) = 290 \\ \text{Sides} \qquad \qquad \qquad \text{(approx)} \end{aligned}$$

- Roof Form Work Erection

→ It has been advised by a groundworker at Persimmon Homes that it "Roughly" would take 5 days to erect form work to cover an area of 500m^2

- Concreting Roof

→ Assume 150mm Roof Slab

→ Area to cover = 500m^2

$$\therefore \text{Volume} = 75\text{m}^3$$

→ Planning Plant to place 150mm of concrete using ready mix = 2.13 hours / per m^3

$$\therefore 2.13 \times 75 = 159 \text{ hours}$$

- Roof Asphalting

→ Planning Plant → 2 man gang = $45\text{m}^2/\text{day}$

$$\frac{500}{45} = \text{approx } 11 \text{ days}$$

Appendix C – Summary of Production Days for TasksSummary of Production Days for Tasks

- Secure Site = 2 days
- Set up Office and Welfare facilities = 2 days
- Install Temporary Services = 2 days
- Material and Plant Storage = 21 days
- Excavation of Existing Car Park = 20.7 days
2 gangs of 5 labourers
 $= 20.7 \text{ days}$
 $\therefore 21 \text{ days}$
- Removal of Spoil Material
 $= 7 \text{ days}$ $= 3.5 \text{ days}$
2 trucks/labours
- Guide Wall construction = 9 days
- Pre-excavation for diaphragm wall = 29 days
- Desanding/Cleaning of Wall = 4.35 days
- Reinforcement Cage Placement = 5.5 days
- Concrete and Tremieing = 8.1 days
- Joining of Wall Sections = 8.75 days
- Excavation of Basement = 7.0 days
3 gangs of 5 labourers
 $= 16 \text{ days}$

- Column and Floor slab construction

→ Sub-block A = $\frac{5 \text{ weeks}}{2 \text{ cranes}} = 2.5 \text{ weeks } 12 \text{ days}$

→ Sub-block B = $\frac{7 \text{ weeks}}{2 \text{ cranes}} = 3.5 \text{ weeks } 17 \text{ days}$

→ Sub-block C = $\frac{11 \text{ weeks}}{3 \text{ cranes}} = 3.7 \text{ weeks } 18 \text{ days}$

→ Sub-block D = $\frac{15 \text{ weeks}}{4 \text{ cranes}} = 3.8 \text{ week } 19 \text{ days}$

- Exterior Walls - Pre-cast Cross Wall Installation

→ Sub-block A = $1.5 \text{ weeks } 7 \text{ days}$

→ Sub-block B = $2 \text{ weeks } 10 \text{ days}$

→ Sub-block C = $3.25 \text{ weeks } 16 \text{ days}$

→ Sub-block D = $4.35 \text{ weeks } 21 \text{ days}$

Repeat this per block

- Roof Form work and Erection = 5 days

- Concrete Roof = $\frac{20 \text{ days}}{2 \text{ gangs of } 10 \text{ labourers}} = 2 \text{ days}$

- Roof Asphaltting = $\frac{11 \text{ days}}{4 \text{ gangs of } 2 \text{ labourers}} = 2.75 \text{ days}$

- Removal of Spoil Material = $\frac{106 \text{ days}}{2 \text{ gangs of 3 labourers (and Trucks)}}$
= 17.7 days

- Ground Support

- Drilling Shaft = 1 day
- Anchor Installation = 1 day (including grouting)
- Stressing = 4 days

- Foundations per Block (A, B, C, D)

- Blinding = $\frac{16 \text{ days}}{8 \text{ labourers}} = 2 \text{ days}$
- Drainage and Utilities = 2 days
- Steel Work for Raft = $\frac{5 \text{ days}}{3 \text{ labourers}} = 1.7 \text{ days}$
- Concrete Pour = 2.8 days
10 labourers = 2.8 days
- Curing Period = allow 14 days



Repeat this process for each sub-block

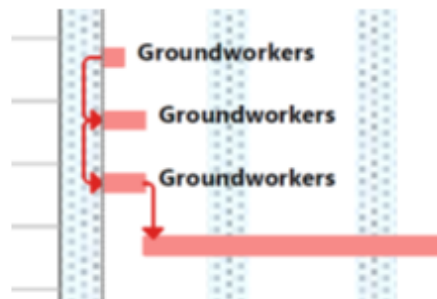
Appendix D – Summary of Gantt Programme

Summary of Gantt Programme

- As you can see below I have calculated total duration for the construction of a multi-story commercial block (which has been split into 4 sub-blocks) to be **261 workings days**, this includes a week off from the 25/12/2017 to 02/01/2018 for the Christmas Period.

Task Name	Duration	Start	Finish
<u>Start and Finish Dates</u>	261 days	Mon 02/10/17	Wed 10/10/18
<u>Site Mobilisation</u>	23 days	Mon 02/10/17	Wed 01/11/17

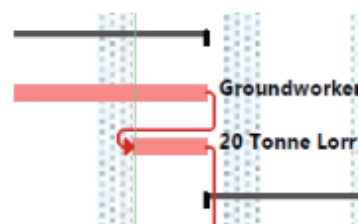
- The construction process begins with the site mobilisation. This includes securing the site, setting up office and welfare facilities, installing temporary supplies (Water and Electric) and finally material and plant storage. All of these tasks except 'material and plant storage' can start at the same time (Start Start) as shown on the Gantt programme;



- As you can see they are linked. This tells us that Task 1, 2 and 3 can all begin at the same time, however task 4 can only begin when task 3 has been completed. This is known as a Finish to Start Link (FS).

As mentioned above, in order to progress onto the next stage of construction, these tasks have to be completed.

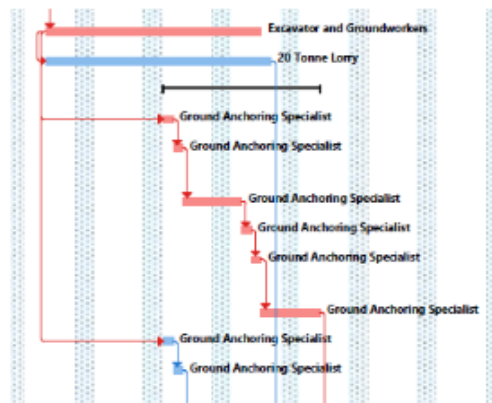
- The next step within this programme is 'Earth Works'. This involves demolishing an existing carpark. I have calculated this to be 21 days. I have also calculated the process of removing this material to be 4 days. As you can see, the 'removal' task doesn't have to begin until 4 days prior to the demolition task to finish;



- Once the earth works have been carried out, the construction of the basement can begin (Diaphragm Wall). As you can see below, each task has a 'Finish to Start' Link, which means the following task cannot begin without the previous one completing.



- Once the diaphragm wall is in place, the ground workers can now begin to excavate the basement. During the excavation of the basement, ground anchors are introduced to support the retaining structure. As you can see the ground anchoring begins half way through the excavation of the basement.



- Once the ground anchoring for each block is complete, the following steps are to construct the foundation. As you can see on the Gantt chart, the foundation for sub-block A cannot start until the ground anchoring for sub-block A is complete, the same relationship with B, C and D.
- As soon as the foundations are complete, the ground workers can now move on to superstructure. As you can see from the task list that the proposed method of construction is Concrete Frame. Similar to the previous point, the superstructure for each block cannot begin until the foundation is complete, here another 'Finish to Start' link.
- The next stage is to construct the roof. This involves shuttering, concrete pouring and asphaltting. Yet again, this process cannot begin until the previous task has been completed.
- It must be noted that I have organised my Gantt programme so that more than 1 block can begin at 1 time. Block A and D begin simultaneously as well as block B and C. By doing this it allows me to reduce the overall construction time making the project more time and possible cost effective.
- One of the key advantages of using a programming software like this, is that it highlights your critical path which has been indicated in red. The critical path is a sequence of tasks which determine the minimum time required for a project.

Critical Progress