

## **2. PROJECT PHASING AND CONSTRUCTION SCHEDULE**

### **2.1 GENERAL**

The construction planning includes not only the time duration of construction activities, but also pre-construction activities. The project phasing and construction schedule is highly site specific. Especially in case of high head hydropower developments the variability of construction schedule is great, due to the variability of the different developments with numerous combination possibilities of components.

Therefore general time schedules cannot be given. For this reason the topic is discussed as general as possible in this chapter and again the construction schedules of two case studies are included in the appendix. Again, similar to the paragraph "Quantity Survey and Cost Estimation", the reservoir project Khan Khwar with 42 MW and the run-of-river project Golen Gol with 106 MW are enclosed with all details of Feasibility Studies.

It should be mentioned in this context, that for the project phasing and construction schedule a lot of experience is needed. Therefore an engineer should carry out this part of the work, whose has spent some years at different construction sites. Because an experienced engineer might have a better knowledge about the difficulties, engineers can face during construction. An experienced engineer might also have a good basis for the estimation of usual works such as excavating, concreting etc.

The basis for the construction schedule is the quantity survey, carried out for the different main structures in the process of cost estimation, discussed in the paragraph above. Based on this quantity survey and the experience for daily progress of work in each working step the construction duration for the different items can be estimated.

The characteristic items of construction process in the project have to be studied in detail and accordingly the construction schedule has to be framed. Also keeping in view the construction methods involved with suitable equipment and machinery required for the project. The period of each activity has to be estimated keeping in view the weather conditions. Especially in high head developments in high mountain areas, extreme climatic conditions have to be considered in the construction schedule. The reason is that some activities may have to be discontinued in severe weather conditions.

Another special site condition for high head developments might be, that the construction area is mostly sloping and steep. Therefore, it does not give too much freedom to locate the required camps, workshops, offices, mixing plants, stores etc. very near to the construction site.

This circumstance makes it sometimes also problematic in respect to the construction material. The most important construction material for all structures is concrete. Therefore sufficient space for crushing plants and mixing plants is needed. The capacity of both the plants is governed by the rate of concrete placement and the size of intermediate stockpiles. Adequate arrangements have to be incorporated in the crushing and screening plants in order to produce aggregates to meet the requirements of the grading curves. This is an urgent prerequisite to ensure the concrete quality. The concrete quality has to be controlled frequently during the construction phase. Laboratory test have to be carried out, sufficient facilities should be made available at the construction site. Moreover during concrete transportation and placement measurements have to be taken to prevent segregation and thereby dangerous reduction of concrete quality.

### **2.2 PROJECT PHASING**

There are different project phases, which have to be distinguished in connection with the tentative construction time schedule:

- Pre-construction

- Construction
- Hydro-mechanical equipment
- Electro-mechanical equipment
- Testing and commissioning

The pre-construction phasing consists in the preparation of detailed drawings and tender documents as well as in the tendering evaluation and awarding.

The construction will be discussed more in detail in the following paragraphs.

Concerning the hydro-mechanical and the electro-mechanical equipment, three different phases have to be distinguished:

- Manufacturing
- Transportation
- Installation

This equipment becomes an important part in the construction during its installation. In case equipment has to be imported from abroad, considerable time for transportation has to be planned.

The testing and commissioning phase starts, when all other works are finalised. Test operation is usually proposed for six months, the phase of commissioning is considered to be finalised after another six months.

### **2.3 CONSTRUCTION TIME SCHEDULE**

The time schedule planning for the construction itself consists, according to the cost estimation, of several main activities, which have to be considered. These activities depend on the layout of the high head development, but in general they can be given as follows:

- Site installation
- Preliminary works
- Construction works reservoir area
- Construction works dam structure / diversion weir
- Construction works waterways
- Construction of the powerhouse
- Electro-mechanical equipment
- Switchyard
- Transmission system

It should be pointed out in this context, that the construction of the waterways can be considered as the most critical point in the construction planning. Especially underground structures as pressure tunnels and shafts, but also surge tanks have a high risk of unforeseens, which might delay the complete schedule.

Another important point is, that many activities start simultaneously at different locations to shorten the total length of the construction. This has the effect, that the logistics of the construction management becomes a decisive aspect for the success of the construction planning.

In the following the different items and activities are briefly discussed. The construction time schedules given in the appendix show the tentative construction schedules for Khan Khwar Hydropower Project and Golen Gol Hydropower Project. They should be studied more in detail, since they can be considered as good examples for possible high head developments in the North of Pakistan.

There is the general tentative time schedule, which covers all works from the pre-construction phase with preliminary works to the commissioning of the project. Apart from that more detailed construction scheduling is available for the most important structures of civil works. The division of activities is mainly based on the sub items of cost estimations for the same structures. Here the quantities play a dominant role in connection with available construction materials. Moreover the interdependence of the activities can be recognised in the detailed time schedules.

#### *Construction Of Camps*

Depending on the main civil structure of the hydropower development and the distances in-between, it might be sometimes necessary to construct two camps. Due to considerable work at the powerhouse, usually one camp is installed near it.

Naturally the camps have to be equipped and furnished with all necessary facilities such as workshops, stores, offices, religious service, accommodations for contractor's and consultant's personnel, hospitals, recreation facilities etc.

#### *Site Installation and Mobilisation*

The first important stage in the construction planning is the site installation. It chiefly deals with the mobilisation of all equipments required for the various construction items, electric and water supplies to offices and equipment, erection of repair and maintenance workshops, stores for spare parts and materials, administration and planning office, concrete mixing plant, aggregate mixing, steel yard, carpenters yard fuel storage stores etc. the area of these items should be as close as possible to the construction site and organised in such a way that no disturbance to the construction programme occurs.

#### *Preliminary Works*

Before the start of any major construction activity, construction, improvement and extension of roads and bridges have to be completed. This is the infrastructural prerequisite for a proper function of the construction for the next years.

#### *Construction Works Reservoir Area*

The construction of reservoirs is sometimes connected with re-location of existing roads. Therefore these works have to be started at the beginning to maintain truck-able public traffic and to avoid inconvenience for the public

#### *Construction Works Dam Structure*

Construction works at the dam site begin with the diversion of the river. If diversion tunnels are constructed, a mean daily progress of about 4 m can be assumed for heading. Rock excavation might be necessary in connection with the construction of the dam. A daily progress of up to 500 m<sup>3</sup> excavation and transport of the excavated material to the disposal area can be taken as rule of thumb.

After completion of excavation works concrete placement including formwork and partly reinforcement is done. The maximum concrete placing volume can be estimated as 250 m<sup>3</sup>/day.

#### *Construction Works Waterways*

The construction works of the waterways are highly dependent on the structures. In general it can be said, that tunnelling works are the most crucial ones. They should start immediately after the preliminary works, since unforeseens might endanger the time scheduling. In most cases, the length depending on the method used by the contractor, either TBM or conventional, the geological conditions and the geometry, the daily progress cannot be expressed in general terms. For this reason no statement is given here, since it might lead to misinterpretations.

Apart from the type of heading, also lining of the tunnel might be necessary, which also takes considerable time in respect to the time schedule.

Today pressure shafts are constructed with help of the raise-boring method. This method can be considered as the most economical method of shaft sinking. The method involves two steps, pilot drilling, from the top to the bottom, and raise boring from the bottom to the top. The construction of the vertical pressure shaft is possible earliest after heading of the horizontal pressure tunnel.

A horizontal pressure tunnel to the pressure shaft, as often used in high head hydropower developments, can also be driven by conventional method.

#### *Construction of the Powerhouse*

The construction of the powerhouse can be distinguished into two parts:

- *Civil works*
- *Assembling of the equipment*

At the beginning preliminary construction works for temporary access roads to the powerhouse area, site installation plants including the crushing plant, workshops and site offices are recommended. The main construction works should start with earth works and excavation of the turbine shaft.

The concrete placement together with formworks and reinforcement are slower compared to the dam, since reinforcement and formworks is considerably large work. Therefore the mean daily progress is reduced to 20 m<sup>3</sup>/day.

The interior civil works in the powerhouse are scheduled in close co-ordination with the assembly works of the powerhouse equipment.

The assembling of the hydro-mechanical equipment will start after assembling of the main crane and auxiliary cranes. Consequently assembling of the turbines will be followed by installation of the generators. Installation of the electrical equipment can start simultaneously.

#### *Electro-Mechanical Equipment*

Manufacturing of electro-mechanical equipment has to be started in co-ordination with the construction time schedule for the powerhouse. Transportation from overseas, if needed, and inland transportation require some months. Installation and commissioning of the equipments may be done during the last six months of the construction period.

#### *Switchyard*

The switchyard is usually located next to the powerhouse. The time duration of construction depends on the site conditions.

#### *Transmission System*

The construction of the transmission system between the hydropower station and the grid should be started early enough to ensure the connection of the station to the grid.

### **2.4 CASH FLOW SCHEDULE OF INVESTMENT**

The cash flow schedule is based on the proposed construction schedules. It is calculated with help of quantity survey and cost estimation described in the previous paragraph. Each item and its cost is connected with the construction time schedule, which gives the cash flow schedule. The calculation can be carried out with a spreadsheet, a detailed example of Khan Khwar is enclosed in the appendix.

Following table provides a compact version of the expenditures of Khan Khwar Hydropower Project

**Table 2.1: Cash flow schedule of investment for Khan Khwar Hydropower Project [1]**

High Head Hydropower  
Economic and Financial Analysis

Year	Quarter	Cash flow in thousand US\$					
		Local		Foreign		Total	
0	1	42		76		118	
	2	42		76		118	
	3	42		76		118	
	4	359	485	76	305	435	790
1	1	1263		1574		2837	
	2	1373		4112		5485	
	3	1259		3977		5236	
	4	804	4699	2149	11812	2953	16512
2	1	1063		2506		3570	
	2	1216		2051		3267	
	3	3321		3945		7266	
	4	4297	9897	5968	14471	10265	24368
3	1	3547		6737		10284	
	2	2873		4254		7127	
	3	1391		2875		4266	
	4	3153	10964	4817	18682	7969	29646
4	1	2070		3248		5319	
	2	1741		2969		4710	
	3	2111		2281		4392	
	4	84	6006	153	8651	237	14658
Total		32051 37%		53921 63%		85974 100%	

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