USE OF GABIONS IN SMALL HYDRAULIC WORKS

SECTION 1

SITE SELECTION FOR SMALL DAMS

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There is a considerable choice of types of hydraulic structures, and deciding which particular one to adopt will largely depend on the uses it will be put to, and on the overall conditions of the area where it will be installed. In choosing a structure type, the on-site availability of building materials and the skills and experience of local workers should also be verified, with an eye to future maintenance requirements.

The specific characteristics of each structure type should be taken into account to select a structure that meets the demands and conditions of the particular site under consideration. Therefore, it will be useful to provide a general classification of hydraulic works before moving on to the analysis of the site selection procedure. In this chapter, use and hydraulic design are introduced as two general criteria for the classification of hydraulic works. The following chapters will mainly focus on most commonly small hydraulic works.

Once the type of hydraulic structure has been selected, further inquiries will allow us to decide about its feasibility and design. The investigation procedure is described in the final part of this chapter.

1.1 – CLASSIFICATION ACCORDING TO USE

Hydraulic works can be classified by use in three main categories, as shown in the table below:

HYDRAULIC WORKS CLASSIFICATION

USE	SUB-CLASS	HYDRAULIC DESIGN
WATER SUPPLY	RETENTION DAMS	Earthfill dams
	DIVERSION WEIR	Gabions weirs with outlet system
FLOOD REGULATION	DEBRIS/CHECK DAMS	Gabions weirs
	DETENTION DAMS	Earthfill dams with outlet system
	WATER SPREADING DAMS	Gabions weirs with earthfill embankment
PROTECTION OF FLOODPLAINS FROM INUNDATION	LEVEES	Earthfill dikes

WATER SUPPLY

The first category refers to structures the main function of which is the supply of water for human needs, livestock watering, and crop irrigation. **Retention structures** are generally used in conjunction with substantial seasonal runoff variations. The required storage volume is established according to local water requirements and runoff fluctuations. For example, in arid and semi-arid regions, earthfill dams are used to stock water during the rainy season, making it available for consumption in the dry season. **Diversion weirs** can only be built if the runoff rate tends to be constant throughout the year.

FLOOD REGULATION

Hydraulic works for flood regulation are structures used to control water runoff effects, mitigating erosion phenomena. **Debris and check** dams are built on small streams to diminish the bed gradient and to reduce runoff transportation. In **detention dams**, the runoff is stored only temporarily, to be gradually released through an outlet system. **Water spreading dams** are used to build up the streambed causing floodplain inundation in areas where runoff overflow is an important factor in groundwater recharge and irrigation practices.

PROTECTION OF FLOODPLAINS FROM INUNDATION

Instead, when floodplains are frequently threatened by runoff overflow or sea tides, they have to be protected with **levees** to secure their utilisation.

In the majority of cases, hydraulic works can be profitably built to meet more than one purpose. For example, a detention dam can be equipped with a small storage volume for water supply, or a diversion dam can also be used to cause floodplain inundation.

While projecting hydraulic works, a serious effort should be made to optimise locally available water resources, especially in arid and semi-arid regions, where the latter are very scarce. Hence, in the case of water storage structures, high evaporation rates should always be taken into consideration, in order to prevent the loss of an important percentage of stored waters. In these instances it might be preferable to opt for a subsurface storage system, functioning through some artificial groundwater recharge mechanism, provided that the local environmental conditions allow it.

Especially working in arid and semi-arid regions, one should never lose sight of the eventual consequences that the installation of hydraulic works might generate downstream. For example, storage or diversion dams can cause water scarcity downstream.

1.2 – CLASSIFICATION BY HYDRAULIC DESIGN (site and basin requirements)

With reference to design, small hydraulic works can be divided in the following main classes (see fig. 1.1, 1.2 an 1.3):

- earthfill dams,
- gabions weirs,
- earthfill dikes.

Fig. 1.1 - Earthfill dam

Fig. 1.2 - Gabions weir

Fig. 1.3 - Earthfill dike

Each of these classes is briefly described below together with site and watershed main requirements.

EARTHFILL DAMS

This class refers to earthfill embankments built on small catchment areas in order to store water. Embankments are constructed with the rolled-fill technique. Embankment height generally does not exceed 10-12 m and its length is less than 1 km, but minor variations may occur, depending on the site topography.

They are generally equipped with both a spillway and an outlet system. To prevent the structure's overflow, the spillway should be designed to evacuate the maximum water-flow during runoff events. Gabions should always be installed to protect the spillway from erosion. A pipeline next to one of the embankment shoulders generally functions as an outlet system. It can be used in storage dams to let water out from the reservoir, or in detention dams to release runoff water gradually. The pipeline's diameter is determined according to the amount of water it will have to support. A gate system might be set up to control the flow's rate.

The reservoir capacity is established on the basis of the purpose it will be put to and of local runoff characteristics. It corresponds to the sum of storage and detention volumes.

Site features:

- availability of construction materials (proper kind of earth; water availability),

- wide impounding reservoir in relation to runoff volume, with impervious substrate,
- low stream transportation rates to retard reservoir sedimentation,
- short distance from a frequented water point (storage dams),
- soil characteristics adequate to support embankment loads and to avoid excessive water seepage.

Watershed features:

- basin runoff characteristics (e.g. volume, temporal variability) meeting structural requirements.

GABIONS WEIRS

Gabion weirs function as cross structures, which build up the streambed and stabilise the bed shape. Weir height is generally limited to 2-4 m to prevent damages downstream caused by local erosion phenomena, which could provoke the structure's breakdown. During floods, depending on runoff conditions and cross section topography, their presence might result in a lateral water overflow, which could be avoided by building earthfill embankments on the wings. Embankment's height generally does not exceed a few meters (3-4 m).

Diversion structures are generally equipped with outlet systems, gated or non-gated, which allow the diversion of runoff waters. Outlet systems will need to be protected against particularly violent runoff events.

Site features:

- availability of construction materials (stones, proper kind of earth and water for embankments and foundations)
- stream cross section allowing flow passage without giving rise to an important specific charge,
- relatively straight longitudinal stream section, avoiding bank erosion downstream the structure,
- wide impounding reservoir, with pervious substrate (water spreading dams),
- compatibility between stream bed level and outlet level (diversion structures),
- potential for series positioning along the stream (debris and check dams),
- soil characteristics adequate to support structure loads.

Watershed features:

- appropriate basin runoff characteristics (e.g. volume, temporal variability).

EARTHFILL DIKES

These are earthfill embankments built in the vicinity of stream banks to protect floodplains from inundations. Embankment height generally does not exceed a few meters (3-4 m) and its length can reach a few kilometres, according to site topography. They are generally endowed with a gated outlet system, to allow the passage of water between floodplains and stream, if required.

Site features:

- availability of construction materials (proper kind of earth and water for embankments and foundations)
- site topography fitting structure purposes.

1.3 – INVESTIGATION PHASE

Firstly, the type of hydraulic work must be chosen, according to the function it will have to fulfil in the area taken into consideration. Then, further inquiries should be carried out to cover all the aspects of structure planning, projecting and building. The investigation phase can be divided in different steps:
preliminary feasibility,
preliminary site survey,
feasibility,
definitive project.

The following description provides a general outline of the various investigation steps: a more detailed analysis (e.g. referring to elements of geohydrology, hydrology, geotechnics) can be found in the next chapter.

Preliminary feasibility

The first step involves the collection of all available data that might result useful at different phases of the project stage.

- cartography, thematic mapping (geology, hydrogeology, soil usage and vegetation cover), aerial photos, satellite images (Spot, Landsat TM, Sar, Ikonos, etc.),
- hydrological data (runoff and sediment transportation), hydrogeological data (groundwater), meteorological data (rainfall and evapotranspiration) and geological data (soils composition),
- general data on population, agriculture and livestock.

We will then have to proceed to a preliminary site selection according to use and type of structure, on the basis of the data collected during the previous research stage.

Once the site has been chosen, we will have to mark the watershed and to classify it according to its topography, geology and drainage features. It is possible to choose among several classification methods. Having selected the one which best suits our specific requirements we should refer to existing data on runoff characteristics made available by previous investigations carried out on similar watersheds.

We now have to verify if local water needs are met, on the basis of our knowledge of runoff characteristics, and to determine if, from the data collected, it is possible to envisage any obstacle that might occur at the building phase.

If similar hydraulic works already exist in the same area, we should examine them closely, assessing their impact and effects on the environment.

Preliminary site survey

If our data suggest that in the site being considered there are all the prerequisites for the installation of a hydraulic structure, a preliminary site inspection is needed to verify if topography, soil structure, and other relevant requirements are met.

If so, we can move on to a preliminary topographic survey of cross and longitudinal stream sections, which will allow us to determine the structure's dimensions. A preliminary soil survey is also necessary to verify if local soil characteristics meet all the structural requirements, and if suitable construction materials are available in the vicinities.

Feasibility

If the data collected during the preliminary site survey confirm that the site is definitely suitable for the kind of hydraulic structure we consider building, we can deepen our analysis.

In-depth topographic and soil surveys should be carried out in all the areas that will accommodate the structure and reservoir, in order to estimate the reservoir's capacity and to know the soil's characteristics. Prospect pits in the quarry area will provide us with data on the characteristics of local construction materials and their available quantities. Especially with regards to earthfill dams, it is necessary to make some soil borings in the embankment's footprint to know the depth, thickness and geotechnical features of the subsoil layers.

At this point we have to do a preliminary structure project to establish the quantity of materials required and the means necessary to build the structure. In line with cost effectiveness and durability concerns, it is a priority to make a project that relies on local means and materials available on-site, and suits local topographic and geological features. For example, with regards to earthfill dams, the spillway's cost usually takes up a high percentage of the total. The presence of favourable natural conditions, such as a saddle in the shoulder, should be established in advance and eventually exploited to substantially reduce the spillway's cost. Also water deficiency, in the surroundings of an earthfill dam, would hinder an adequate compaction of the embankment.

In this phase it is also necessary to prepare a general work plan. For example, if a temporary stream diversion is required during structure building, performing this costly operation can strongly affect the overall structure's costs.

We can now estimate the total costs of building the structure, which should be compared to the benefits that could be derived from its installation. This particular kind of cost/benefit analysis is highly delicate, as it is very difficult to quantify some effects, such as runoff retention or groundwater recharge.

Definitive project

If all the investigations confirm that the designed hydraulic work can be conveniently built in the chosen site, we can move on to the definitive structure project. However, before doing so, it will be useful to complete the topographic and soil surveys started at the previous investigation phase.

All the substructures must now be designed and verified. Firstly, all structural characteristics, such as storage and detention volume for an earthfill dam, or weir height for a diversion dam, must be calculated. The spillway's dimensions should also be accurately calculated at an early stage, as a very common cause for the failure of hydraulic works is the structure's overtopping caused by miscalculations of the spillway's characteristics.

A topographic plan and cross section must be designed for every structure. Cross section structures must be designed for all the appropriate load combinations and tested against hydraulic seepage. Particular specifications have to be defined prior to the installation of construction materials, such as stone size for gabions filling and moisture content for earthfill materials.

We have to prepare a detailed work plan for each phase of the construction, trying to optimise the utilisation of available means.

Various types of inquiry should be conducted at the same time, in order to advance our understanding of the site's characteristics and requirements. Preliminary and progressive structure projects have to be prepared to evaluate the works' feasibility. At an early stage of our investigations, it will be convenient to consider different solutions, as if we were carrying out several projects at the same time. This will allow us to progressively contrast the respective costs and benefits of different solutions, until we are able to select one of them. At this point the related inquiries become more focused.

These investigations require various kinds of expertise. Ideally, a team of experts, comprising at least a hydrologist, a geotechnical specialist and a hydraulic engineer, should be formed on purpose. In developing countries it is often very difficult to gather all the data required for projecting a small hydraulic work. Therefore, the designer will have to extrapolate the required data from other sources.

Various types of **supports** will be required throughout the investigation phases, such as general topographic survey equipment, a geo-technical kit and a computer with various software tools. For example, a proper ***GIS tools*** will result helpful throughout the initial investigations on watershed features, a ***CAD tools*** is necessary for the elaboration of data gathered during the reservoir survey, and ***hydrological and hydraulic software tools*** might be useful in the estimation of various hydraulic structures' features.

The extent of the enquiries and the personnel involved should be commensurate to the magnitude of the works to be implemented, lest preliminary studies take up a disproportionate stake of the available funds. With reference to the procedures described above, investigations concerning minor hydraulic works should be substantially simplified.

It is fundamental, in the final work project, to take into consideration future **maintenance concerns**. In fact, it is not uncommon for minor damages left un-repaired to be at the origin of severe structure's breakdowns. This is why, starting from the design stage, great care should be taken in minimising maintenance tasks. All aspects of ordinary maintenance should also be covered.