SSIGL 20

# NATIONAL GUIDELINES

## For Small Scale Irrigation Development in Ethiopia

## Quantity Surveying

November 2018

Addis Ababa

*MINISTRY OF AGRICULTURE*

*National Guidelines for Small Scale Irrigation Development in Ethiopia*

# SSIGL 20: Quantity Surveying

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**First Edition 2018**



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***Financed by Agricultural Growth Program (AGP)***

***DISCLAIMER***

*Ministry of Agriculture through the Consultant and core reviewers from all relevant stakeholders included the information to provide the contemporary approach about the subject matter. The information contained in the guidelines is obtained from sources believed tested and reliable and are augmented based on practical experiences. While it is believed that the guideline is enriched with professional advice, for it to be successful, needs services of competent professionals from all respective disciplines. It is believed, the guidelines presented herein are sound and to the expected standard. However, we hereby disclaim any liability, loss or risk taken by individuals, groups, or organization who does not act on the information contained herein as appropriate to the specific SSI site condition.*

# FORWARD

Ministry of Agriculture, based on the national strategic directions is striving to meet its commitments in which modernizing agriculture is on top of its highest priorities to sustain the rapid, broad-based and fair economic growth and development of the country. To date, major efforts have been made to remodel several important strategies and national guidelines by its major programs and projects.

While efforts have been made to create access to irrigation water and promoting sustainable irrigation development, several barriers are still hindering the implementation process and the performance of the schemes. The major technical constrains starts from poor planning and identification, study, design, construction, operation, and maintenance. One of the main reasons behind this outstanding challenge, in addition to the capacity limitations, is that SSIPs have been studied and designed using many ad-hoc procedures and technical guidelines developed by various local and international institutions.

Despite having several guidelines and manuals developed by different entities such as MoA (IDD)-1986, ESRDF-1997, MoWIE-2002 and JICA/OIDA-2014, still the irrigation professionals follow their own public sources and expertise to fill some important gaps. A number of disparities, constraints and outstanding issues in the study and design procedures, criteria and assumptions have been causing huge variations in all vital aspects of SSI study, design and implementation from region to region and among professionals within the same region and institutions due mainly to the lack of agreed standard technical guidelines. Hence, the SSI Directorate with AGP financial support, led by Generation consultant (GIRDC) and with active involvement of national and regional stakeholders and international development partners, these new and comprehensive national guidelines have been developed.

The SSID guidelines have been developed by addressing all key features in a comprehensive and participatory manner at all levels. The guidelines are believed to be responsive to the prevalent study and design contentious issues; and efforts have been made to make the guidelines simple, flexible and adaptable to almost all regional contexts including concerned partner institution interests. The outlines of the guidelines cover all aspects of irrigation development including project initiation, planning, organizations, site identification and prioritization, feasibility studies and detail designs, contract administration and management, scheme operation, maintenance and management.

Enforceability, standardization, social and environmental safeguard mechanisms are well mainstreamed in the guidelines, hence they shall be used as a guiding framework for engineers and other experts engaged in all SSI development phases. The views and actual procedures of all relevant diverse government bodies, research and higher learning institutions, private companies and development partners has been immensely and thoroughly considered to ensure that all stakeholders are aligned and can work together towards a common goal. Appropriately, the guidelines will be familiarized to the entire stakeholders working in the irrigation development. Besides, significant number of experts in the corresponding subject matter will be effectively trained nationwide; and the guidelines will be tested practically on actual new and developing projects for due consideration of possible improvement. Hence, hereinafter, all involved stakeholders including government & non-governmental organizations, development partners, enterprises, institutions, consultants and individuals in Ethiopia have to adhere to these comprehensive national guidelines in all cases and at all level whilst if any overlooked components are found, it should be documented and communicated to MOA to bring them up-to-date.

Therefore, I congratulate all parties involved in the success of this effort, and urge partners and stakeholders to show a similar level of engagement in the implementation and stick to the guidelines over the coming years.

H.E. Dr. Kaba Urgessa
State Minister, Ministry of Agriculture

## SMALL SCALE IRRIGATION DEVELOPMENT VISION

*Transforming agricultural production from its dependence on rain-fed practices by creating reliable irrigation system in which smallholder farmers have access to at least one option of water source to increase production and productivity as well as enhance resilience to climate change and thereby ensure food security, maintain increasing income and sustain economic growth.*

## ACKNOWLEDGEMENTS

The preparation of SSIGLs required extensive inputs from all stakeholders and development partners. Accordingly many professionals from government and development partners have contributed to the realization of the guidelines. To this end MOA would like to extend sincere acknowledgement to all institutions and individuals who have been involved in the review of these SSIGLs for their comprehensive participation, invaluable inputs and encouragement to the completion of the guidelines. There are just too many collaborators involved to name exhaustively and congratulate individually, as many experts from Federal, regional states and development partners have been involved in one way or another in the preparation of the guidelines. The contribution of all of them who actively involved in the development of these SSIGLs is gratefully acknowledged. The Ministry believes that their contributions will be truly appreciated by the users for many years to come.

The Ministry would like to extend its appreciation and gratitude to the following contributors:

- Agriculture Growth Program (AGP) of the MoA for financing the development and publication of the guidelines.
- The National Agriculture Water Management Platform (NAWMP) for overseeing, guidance and playing key supervisory and quality control roles in the overall preparation process and for the devotion of its members in reviewing and providing invaluable technical inputs to enrich the guidelines.
- Federal Government and Regional States organizations and their staff for their untiring effort in reviewing the guidelines and providing constructive suggestions, recommendations and comments.
- National and international development partners for their unreserved efforts in reviewing the guidelines and providing constructive comments which invaluably improved the quality of the guidelines.
- Small-scale and Micro Irrigation Support Project (SMIS) and its team for making all efforts to have quality GLs developed as envisioned by the Ministry.

The MOA would also like to extend its high gratitude and sincere thanks to AGP's multi development partners including the International Development Association (IDA)/World Bank, the Canada Department of Foreign Affairs, Trade and Development (DFATD), the United States Agency for International Development (USAID), the Netherlands, the European Commission (EC), the Spanish Agency for International Development (AECID), the Global Agriculture and Food Security Program (GAFSP), the Italy International Development Cooperation, the Food and Agriculture Organization (FAO) and the United Nations Development Program (UNDP).

Moreover, the Ministry would like to express its gratitude to Generation Integrated Rural Development Consultant (GIRDC) and its staff whose determined efforts to the development of these SSIGLs have been invaluable. GIRDC and its team drafted and finalized all the contents of the SSIGLs as per stakeholder suggestions, recommendations and concerns. The MoA recognizes the patience, diligence, tireless, extensive and selfless dedication of the GIRDC and its staff who made this assignment possible.

Finally, we owe courtesy to all national and International source materials cited and referred but unintentionally not cited.

Ministry of Agriculture

## DEDICATIONS

*The National Guidelines for Small Scale Irrigation Development are dedicated to Ethiopian smallholder farmers, agro-pastoralists, pastoralists, to equip them with appropriate irrigation technology as we envision them empowered and transformed.*

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# ACRONYMS

| | |
|---|---|
| AGP | Agricultural Growth Project |
| BOQ | Bills of Quantities |
| CAD | Computer Aided Design |
| CM | Centimeter or Construction Management |
| DDT | Deduction |
| DN | Nominal Diameter |
| ESCP | Ethiopian Standard Code of Practice |
| ETB | Ethiopian Birr |
| GI pipe | Galvanized Iron pipe |
| GIRDC | Generation Integrated Rural Development Consultant |
| GS pipe | Galvanized Steel pipe |
| IDA | International Development Association |
| IDSAA | Irrigation Development and Schemes Administration Agencies |
| ILO | International Labour Organization |
| kg | kilogram |
| km | kilometer |
| LWF | Lutheran World Federation |
| m2 | square meter |
| m3 | cubic meters |
| MD | Man-day |
| MOA | Ministry of Agriculture |
| MOWR | Ministry of Water Resources |
| NGO | Non-Governmental Organization |
| OGL | Original Ground Level |
| ONRS | Oromia National Regional State |
| OWWCE | Oromia Water Works Construction Enterprise |
| PAH | Project Administration Handbook for Civil Engineering Works |
| PVC | Polyvinyl Chloride |
| QS | Quantity Survey |
| RC | Reinforced Concrete |
| RCC | Roller-Compacted Concrete |
| RF | Reinforcement |
| SMM | Standard Method of Measurement |
| SNNPRS | Southern Nations Nationalities Peoples Regional State |
| SPID | Standard Phraseology of Item Descriptions |
| SSID | Small Scale Irrigation Development |
| SSIGL | Small Scale Irrigation Guideline |
| SSIP | Small Scale Irrigation Project |
| SSIS | Small Scale Irrigation Scheme |
| TOS | Takeoff Sheet |
| UF | Utilization Factor |
| URA | Unit Rate Analysis |

# PREFACE

While irrigation development is at the top of the government's priority agendas as it is key to boost production and improve food security as well as to provide inputs for industrial development. Accordingly, irrigated land in different scales has been aggressively expanding from time to time. To this end, to enhance quality delivery of small-scale irrigation development planning, implementation and management, it has been decided to develop standard SSI guidelines that must be nationally applied. In September 2017 the Ministry of Agriculture (MoA) had entrusted Generation Integrated Rural Development Consultant (GIRDC) to prepare the National Small-scale Irrigation Development Guidelines (SSIGLs).

Preparation of the SSIGLs for enhancing development of irrigated agriculture is recognized as one of the many core initiatives of the MoA to improve its delivery system and achieve the targets in irrigated agriculture and fulfill its mission for improving agricultural productivity and production. The core objective of developing SSIGLs is to summarize present thinking, knowledge and practices to enable irrigation practitioners to properly plan, implement and manage community managed SSI schemes to develop the full irrigation potential in a sustainable manner.

As the SSIGLs are prepared based on national and international knowledge, experiences and practices, and describe current and recommended practice and set out the national standard guides and procedures for SSI development, they serve as a source of information and provide guidance. Hence, it is believed that the SSIGLs will contribute to ensuring the quality and timely delivery, operation and maintenance of SSI schemes in the country. The SSIGLs attempt to explain and illustrate the important concepts, considerations and procedures in SSI planning, implementation and management; and shall be used as a guiding framework for professionals engaged in SSI development. Illustrative examples from within the country have been added to enable the users understand the contents, methodologies presented in the SSIGLs.

The intended audiences of the SSIGLs are government organizations, NGOs, CSOs and the private sector involved in SSI development. Professionally, the SSIGLs will be beneficial for experienced and junior planners, experts, contractors, consultants, suppliers, investors, operators and managers of SSI schemes. The SSIGLs will also serve as a useful reference for academia and researchers involved and interested in SSI development. The SSIGLs will guide to ensure that; planning, implementation and management of SSI projects is formalized and set procedures and processes to be followed. As the SSIGLs provide information and guides they must be always fully considered and applied by adapting them to the local specific requirements.

In cognizance with the need for quality SSIGLs, the MoA has duly considered quality assurance and control during preparation of the guidelines. Accordingly, the outlines, contents and scope of the SSIGLs were thoroughly discussed, reviewed and modified by NAWMP members (senior professionals from public, national and international stakeholder) with key stakeholders in many consultative meetings and workshops. Moreover, at each milestone of SSIGL preparation, resource persons from all stakeholders reviewed and confirmed that SSIGLs have met the demands and expectations of users.

Moreover, the Ministry has mobilized resource persons from key Federal, National Regional States level stakeholders and international development partners for review, validation and endorsement of the SSIGLs.

Several hundreds of experienced professionals (who are very qualified experts in their respective fields) from government institutions, relevant private sector and international development partners have significantly contributed to the preparation of the SSIGLs. They have been involved in all aspects of the development of SSIGLs throughout the preparation process. The preparation process included a number of consultation meetings and workshops: (i) workshop to review inception report, (ii) workshop on findings of review of existing guidelines/manuals and proposed contents of the SSIGLs, (iii) meetings to review zero draft SSI GLs, (iv) review workshop on draft SSI GLs, (v) small group review meetings on thematic areas, (vi) small group consultation meetings on its final presentation of contents and layout, (vii) consultation mini-workshops in the National States on semi-final versions of the SSIGLs, and (viii) final write-shop for the appraisal and approval of the final versions of SSIGLs.

The deliberations, concerns, suggestions and comments received from professionals have been duly considered and incorporated by the GIRD Consultant in the final SSIGLs.

There are 34 separate guidelines which are categorized into the following five parts concurrent to SSI development phases:

Part-I. Project Initiation, Planning and Organization Guideline which deals with key considerations and procedures on planning and organization of SSI development projects.

Part-II. Site Identification and Prioritization Guideline which treats physical potential identification and prioritization of investment projects. It presents SSI site selection process and prioritization criteria.

Part-III. Feasibility Study and Detail Design Guidelines for SSID dealing with feasibility study and design concepts, approaches, considerations, requirements and procedures in the study and design of SSI systems.

Part-IV. Contract Administration and Construction Management Guidelines for SSI development presents the considerations, requirements, and procedures involved in construction of works, construction supervision and contract administration.

Part-V. SSI Scheme Management, Operation and Maintenance Guidelines which covers SSI Scheme management and operation.

Moreover, Tools for Small Scale Irrigation development are also prepared as part of SSIGLs.

It is strongly believed and expected that; the SSIGLs will be quickly applied by all stakeholders involved in SSI development and others as appropriate following the dissemination and familiarization process of the guidelines in order to ensure efficient, productive and sustainable irrigation development.

The SSIGLs are envisioned to be updated by incorporating new technologies and experiences including research findings. Therefore, any suggestions, concerns, recommendations and comments on the SSIGLs are highly appreciated and welcome for future updates as per the attached format below. Furthermore, despite efforts in making all types of editorial works, there may still errors, which similarly shall be handled in future undated versions.

# UPDATING AND REVISIONS OF GUIDELINES

The GLs are intended as an up-to-date or a live document enabling revisions, to be updated periodically to incorporate improvements, when and where necessary; may be due to evolving demands, technological changes and changing policies, and regulatory frameworks. Planning, study and design of SSI development interventions is a dynamic process. Advancements in these aspects are necessary to cope up with the changing environment and advancing techniques. Also, based on observation feedbacks and experiences gained during application and implementation of the guidelines, there might be a need to update the requirements, provisions and procedures, as appropriate. Besides, day-by-day, water is becoming more and more valuable. Hence, for efficient water development, utilization and management will have to be designed, planned and constructed with a new set up of mind to keep pace with the changing needs of the time. It may, therefore, be necessary to take up the work of further revision of these GLs.

This current version of the GLs has particular reference to the prevailing conditions in Ethiopia and reflects the experience gained through activities within the sub-sector during subsequent years. This is the first version of the SSI development GLs. This version shall be used as a starting point for future update, revision and improvement. Future updating and revisions to the GLs are anticipated as part of the process of strengthening the standards for planning, study, design, construction, operation and management SSI development in the country.

Completion of the review and updating of the GLs shall be undertaken in close consultation with the federal and regional irrigation institutions and other stakeholders in the irrigation sub-sector including the contracting and consulting industry.

In summary, significant changes to criteria, procedures or any other relevant issues related to technological changes, new policies or revised laws should be incorporated into the GLs from their date of effectiveness. Other minor changes that will not significantly affect the whole nature of the GLs may be accumulated and made periodically. When changes are made and approved, new page(s) incorporating the revision, together with the revision date, will be issued and inserted into the relevant GL section.

All suggestions to improve the GLs should be made in accordance with the following procedures:

I. Users of the GLs must register on the MOA website: Website: www.moa.gov.et
II. Proposed changes should be outlined on the GLs Change Form and forwarded with a covering letter or email of its need and purpose to the Ministry.
III. Agreed changes will be approved by the Ministry on recommendation from the Small-scale Irrigation Directorate and/or other responsible government body.
IV. The release date of the new version will be notified to all registered users and authorities.

Users are kindly requested to present their concerns, suggestions, recommendations and comments for future updates including any omissions and/or obvious errors by completing the following revisions form and submitting it to the Ministry. The Ministry shall appraise such requests for revision and will determine if an update to the guide is justified and necessary; and when such updates will be published. Revisions may take the form of replacement or additional pages. Upon receipt, revision pages are to be incorporated in the GLs and all superseded pages removed.

**Suggested Revisions Request Form (Official Letter or Email)**

To: ----------
From: ----------
Date: ----------
**Description of suggested updates/changes:** Include GL code and title, section title and # (heading/subheading #), and page #.

| GL Code and Title | Date | Sections/ Heading/Subheading/ Pages/Table/Figure | Explanation | Comments (proposed change) |
|---|---|---|---|---|
| | | | | |
| | | | | |

Note that be specific and include suggested language if possible and include additional sheets for comments, reference materials, charts or graphics.

**GLs Change Action**

| Suggested Change | Recommended Action | Authorized by | Date |
|---|---|---|---|
| | | | |
| | | | |
| | | | |

Director for SSI Directorate**: _____Date: _____**

The following table helps to track initial issuance of the guidelines and subsequent Updates/Versions and Revisions (Registration of Amendments/Updates).

**Revision Register**

| Version/Issue/Revision No | Reference/Revised Sections/Pages/topics | Description of revision (Comments) | Authorized by | Date |
|---|---|---|---|---|
| | | | | |
| | | | | |
| | | | | |

# 1 INTRODUCTION

## 1.1 BACKGROUND

This is part of the Guideline prepared for SSIPs and is produced to enable to lay the criteria to be considered, the basic approaches and procedures to be followed and techniques of quantity surveying including unit rate analysis, preparation of takeoff sheet, BOQ, cost estimate and the documentation that is required in the measurement of engineering works for common activities to be carried out in small scale irrigation projects (SSIPs) development.

Bill of quantity is a schedule of different construction material or parts chronological list indicating the type and specification of construction material and its corresponding quantity. The Bill of quantity is thus, a valuable source of construction material quantity that gives information to the cost estimator. Besides this, the bill of quantity is basis for preparation of construction planning, budgeting purposes and payment to the contractor. The bill of quantities in general contains items for the construction, installation, testing and commissioning work to be executed by the contractor.

The bill of quantities is therefore used to determine the contract price and the contractor thus is paid for the quantity of the work done at the rate presented for each item in the bill of quantities. If requested by the employer, the contractor shall provide a detailed cost breakdown of any rate in the bill of quantities.

## 1.2 SCOPE OF THIS GUIDELINE

As the purpose of this guideline is for the aid of small scale irrigation scheme design, its scope is also limited to quantity surveying including unit rate analysis, preparation of takeoff sheet, BOQ and cost estimate.

This guideline is thus prepared to assist practicing engineers to get familiar with different aspects of rate build up and preparation of BOQ and pre-, during- and post-construction measurement procedures with the aid of basic concept demonstration, worked example and templates. Thus, its scope covers considerations of these important skeletons of construction industry, including worked examples with respect to quantifications and rate analysis using excel software for different parts of items of irrigation and drainage works.

## 1.3 TECHNICAL DEFINITIONS OF TERMINOLOGIES USED IN THE GUIDELINE

**As-built drawings** or **Record drawings:** are approved drawings as built on the ground and to be used by the beneficiaries for scheme operation, maintenance and rehabilitation. It is also called **shop drawings** when the Contractor is expected to modify the designs and drawings (if need be or as may be required by the Project Manager depending on actual encountered ground condition).

**Auto CAD:** is a design and drafting software used for creating precise engineering drawings. It is a language for interpreting designs in to models.

**Backfill and compaction:** is activity carried out by manually filling and compacting selected material at the back of a structure soon after its construction is completed.

**Bill of quantity**: is a detailed statement of works, unit and total prices, dimensions, specifications and other details required for the erection of designed structures. It is a set of declaration of items of works with which tender is prepared and contract is signed in between the two parties (the client and the contractor). Thus, bill of quantity is a chronologically billed item of work specifying quantity of work with its corresponding units of measurement and is derived from takeoff sheet**.**

**Community:** refers to individuals or groups of project beneficiaries and others who involve the implementation of project activities which can be community groups with no legal status, associations or groups with legal status but with or without separate legal personality as a group, small-scale artisans and other small commercial organizations and unions, and small local-level organizations that support and facilitate rural agricultural and social activities. The community in such cases may participate as procurement agent, implementing agency, or contractor and supplier of goods, works and related services for that project activity.

**Concrete:** is one of the most common SSIP activities constructed from cement, sand and gravel (if plain or lean concrete) otherwise include reinforcement bar (if reinforced concrete).

**Drawing**: is a technical drafting tool, which is used to fully and clearly define requirements for engineered items. It is a tool that describes or puts design of structures in to understandable sizes. It can also be defined literally as a graphical language or art that communicates ideas and information from one mind (the designer) to another (the user).

**Engineering tolerance or Tolerance**: is the permissible limit or limits of variation in a physical dimension or a measured value of physical property of a material, manufactured object, system, or service.

**Excavation**: is the most common labor based activities of SSIP and includes digging in soil, rock (soft or hard), to attain required design level or to obtain construction material for fill or quarry site, or to prepare working area.

**Masonry:** is one of the most common SSIP activities constructed from undressed stone (if below plinth) and dressed stone (if above plinth) and mortar (mix of cement and sand).

**Measurement**: is the transformation of drawn data into description and quantity information. It is not an end in itself. It is a tool to enable other functions. It is done to value, cost, and price construction work, as well as enabling effective management.

**Rate**: is a ratio that is used to compare different kinds of quantities. A unit rate describes how many units of the first type of quantity corresponds to one unit of the second type of quantity.

**Schedules of works**: are instructional lists that allow the contractor to identify significant work and materials that will be needed to complete the works and to calculate the quantities that will be required.

**Site clearing**: is one of the most common SSIP activities and includes removal of all obstacles manually and/or machine based such as grabbing, removal of top soil to a maximum depth of 15 cm, boulders, trees, shrub/bush, grasses, etc. for preparing for excavation works.

**Technical drawing:** is a drawing derived from design of structures which is handed over to the contractor during agreement.

**Takeoff sheet**: Take off, sometimes spelled as "take-off" or "takeoff," is a part of the cost estimating process in the construction industry. Estimators use construction blueprints, either manually or electronically, and start "taking off" quantities of items they will need from those blueprints in order to prepare part of the estimate. It in general, refers to the process of identifying

elements of construction works that can be measured and priced. These elements can then be measured in number, length, area, volume, weight or time then collated and structured to produce an unpriced bill of quantities. It is that part of preparation of bill of quantities, which shows each and every components of the designed structure in all directions, be on the ground or under the ground in its length, width and height. Thus it lays bases for preparation to project BOQ.

**Unit rate**: Unit rate is a rate required to accomplish a unit volume of work. Thus, it is a measure of productivity in terms of cost per unit of work done.

**Utilization factor or use factor**: is the ratio of the time that a labour or equipment or hand tool is in use to the total time that it could be in use. It is often averaged over time in the definition such that the ratio becomes the amount of energy used divided by the maximum possible to be used.

**Working drawings/construction drawings**: provide dimensioned, graphical information that can be used by a contractor to construct the works, or by suppliers to fabricate components of the works or to assemble or install components.

# 2 BILL OF QUANTITIES

## 2.1 GENERAL ASPECTS OF BILLS OF QUANTITIES

Bill of Quantities (BOQ) is a self, qualitative and quantitative description for different elements of works and is subdivided in to a chronological list of each item of work, material or provision included in the project activities, along with an estimate of the quantity required for each class. The quantities and the description of the works are basically derived from the drawings and specifications.

Blank columns should be provided in the table of the BOQ, for tenderers to fill in their unit prices (rates) against each item in tender document. In response to this, bidders fill in the blank space against each work item and present what we call the priced bill of quantities. In addition to this there are cases where only rates are required to be quoted without bill of quantities as for example, supply of imported items like pump, GI pipe, etc. in such case, only rate at the time of bidding is quoted but payment is effected based on the rate delivery of the materials.

It is a document prepared by the cost consultant (often a quantity surveyor) that provides project specific measured quantities of the items of work identified on the drawings and specifications in the tender documentation. The quantities may be measured in units of number, length, area, volume, weight, time or lump sum. Preparing a bill of quantities requires that the design is complete and a specification has been prepared. The bill of quantities is issued to tenderers to enable them prepare a price for carrying out the works. The bill of quantities assists tenderers in the calculation of construction costs for their tender, and, as it means all tendering contractors will be pricing the same quantities (rather than taking-off quantities from the drawings and specifications themselves).

The BOQ in general has the following benefits:

- It provides equal opportunity for all tenderers to enter a unit price or rate against each item. By summing up the total cost for each item, along with the quantities entered by the engineer, the total tender sum is thus derived on a basis common to all tenderers;
- It can provide a basis for making progress payments, deriving costs for additional work and evaluating deductions which could arise as a result of deletion of some items from the contract;
- It is used to know the project cost estimate;
- It helps to know scope of work;
- Thus, it can be used as indicator for the grade of the contractor;
- It forms the basis for tender comparison;
- It provides a means of valuing the works;
- It can be used as reference for cases of adjudication, i.e. it forms a basis for fixing any rates not included in the BOQ, or valuing any variations.

During construction, the actual quantity relating to each item is measured and entered into a blank bill, which is held for measurement and payment purposes. The payment is at the tender rate.

The preamble to the BOQ in the tender documents should clearly indicate any particular obligations imposed by the contract in order to allow tenderers to assess the financial implications.

As an example, the preamble to the BOQ should:

- Direct tenderers to familiarize themselves with the requirements and provisions of the contract documents;
- State the basis upon which the BOQ has been drawn up;
- State that the unit prices should be entered against each item, otherwise it is assumed to be covered elsewhere.

The quantities given in the BOQ are estimates and provisional and are given to provide a common basis for bidding. The basis of payment is the actual quantity of work ordered and carried out, as measured by the contractor and verified by the engineer/supervisor and valued at the rates and prices bid in the priced BOQ.

In its notes for the preparation of BOQ, IDA stated that, the objectives of BOQ are:

- To provide sufficient information on the quantities of Works to be performed to enable bids to be prepared efficiently and accurately; and
- When a contract has been entered into, to provide a priced Bill of Quantities for use in the periodic valuation of Works executed.

The notes further states:

"In order to attain these objectives, Works should be itemized in the Bill of Quantities in sufficient detail to distinguish between the different classes of Works, or between Works of the same nature carried out in different locations or in other circumstances which may give rise to different considerations of cost. Consistent with these requirements, the layout and content of the Bill of Quantities should be as simple and brief as possible."

These works should be listed in sequential numbering system as such numbering is used as code of that item of work in the implementation and payment processes.

## 2.2 COMMON ACTIVITIES IN IRRIGATION PROJECTS

The first approach to this study is to identify common activities to be rated as an assignment. Thus, following lists of activities are the most commonly required items of work in civil works of water resources projects.

- Earthmoving
- Site clearance and removal of top soil to a max. depth of 20 cm
- Excavation in all types of soil except rock and disposal for hauling distance within 500m
- Backfill with selected material from excavation, including compaction
- Fill with selected material from borrow pits within hauling distance of 20 km, including compaction
- Excavation in rock and disposal for haul distance within 500m
- Extra over for above earth works items for hauling distance beyond 500m

These activities are required:

- To burry pipes in to the ground
- Produce a level access and farm road formation platform in virgin terrain
- To obtain material to raise or widen a road
- For the primary activity in producing road side drains, even if the side drain work may be broken down into first digging a trench and then sloping the sides
- In quarries to obtain gravel for surfacing
- To form the embankments of irrigation canals

- To obtain material for small earth dams
- Masonry and Concrete works
- Provide and place stone masonry above/below plinth
- Reinforcement bar, including supply, bend, fix, and the like.
- Provide and placing lean & RCC concrete of different grades
- Form Work, including transporting, placing etc.
- Provide and placing (1:3) 20 mm thick mortar as plastering
- Provide and placing (1.3) mortar for pointing work
- Provide and place hard core
- Provide and place stone Rip Rap
- Mesh/Chicken Wire
- Provision and placing of commonly used concrete works such as C-10 (Lean or plain concrete, 1:4:8), C-15 (mass concrete, 1:3:6), C-20 (RCC concrete, 1:2:4), C-25 (RCC concrete, 1:2:3) and C-30 (RCC concrete, 1:1.5:3), Cyclopean concrete (concrete with 30% boulder stone),
- Gabion works
- Provide, place and fill gabions with stone
- Metalwork /cutting, shaping, welding/
- Pipes of different material and diameter laying/placing including transporting
- Geo-membrane and geo-net lining
- GIS Roofing work (for camping, if need be)
- Pre-cast concrete pipe of different diameter per meter producing, transporting and placing.
- Loading, unloading and spreading, etc.

## 2.3 QUANTITY TAKE-OFF

### *2.3.1 Quantity takeoff and cost estimate*

The quantity “takeoff” is an important part of the cost estimate. It must be as accurate as possible and should be based on all available engineering and design data. Use of appropriate automation tools is highly recommended. Accuracy and completeness are critical factors in all cost estimates. An accurate and complete estimate establishes accountability and credibility of the cost engineer, therefore, providing greater confidence in the cost estimate. The estimate contingencies for programming purposes reflect the estimate confidence.

### *2.3.2 Importance of quantity take-off and required documents*

The quantity of material in a project can be accurately determined from the drawings. The estimator must review each sheet of the drawings, calculate the quantity of material and record the amount and unit of measure. Each estimator must develop a system of quantity takeoff that ensures that a quantity is not omitted or calculated twice. A well-organized check-list of work will help reduce the chances of omitting an item. The estimator must, also, add an appropriate percentage for waste for those items where waste is likely to occur during construction. The material quantity takeoff is extremely important for cost estimating because it often establishes the quantity and unit of measure for the costs of labor and contractor’s equipment.

## 2.4 TAKING OFF

### 2.4.1 General

Taking off is the procedure by which dimensions of the works are calculated or scaled off from the drawings and entered into dimension papers or other similar formats prepared on computers, thus it is source of BOQ. It has the following standard format.

**Table 2-1: Standard Format of Taking off Dimension Paper**

| 1 | 2 | 3 | 4 | 1 | 2 | 3 | 4 |
|---|---|---|---|---|---|---|---|

Descriptions of each column are given here under.

**Column-1**: is the 'timesing' column in which multiplying figures are entered when there is more than one of the particular item being measured.

**Column-2**: is the 'dimension' column in which the actual dimensions taken from the drawings are entered.

**Column-3**: is the 'squaring' column in which the product of the figures in column 1 and column 2 is recorded ready for transfer to the abstract or bill.

**Column-4**: is the 'description' column in which the written description and SPID codes of each item are entered. The right-hand side of this column is known as the 'waste' area. It should be used for preliminary calculations, buildup of lengths, explanatory notes and related matters. All steps that have been taken in arriving at dimensions, no matter how elementary or apparently trivial, should be entered here, as this will neatly aid re-measurement, valuing the works done for interim certificates, and answering any queries regarding the measurements which may arise.

### 2.4.2 Entering dimensions

Dimensions should be entered in a constant order that must be maintained throughout, that is (1) length, (2) breadth or width, and (3) depth or height, so that there can be no doubt as to the shape of the item being measured. If this is not possible, dimensions should be annotated to indicate length, width or breadth, height or depth, diameter, etc. Dimensions should usually be recorded in meters to three decimal places and a line drawn across the dimension column under each set of measurements. Very often when measuring a number of dimensions for one item of construction it will be necessary to deduct some dimensions from the total. To ensure that this is done clearly, it is good practice to enter such dimensions in the timesing column under the heading DDT (meaning deduction).

Many of the words entered in the description column can be abbreviated to save both space and time. Ample space should be left between all items on the dimension sheets so that it is possible to follow the dimensions with ease and to enable any items, which may have been omitted when the dimensions were first taken off, to be inserted subsequently. All entries in the dimension sheet should then be made in ink or blue/black ball pen. Erasable ball pens should not be used. If it becomes necessary to amend any dimensions that have been entered on the dimension paper, this should never be done by the use of correction fluid or eraser, or by altering the actual figures. The correct procedure is to write "Nil" in the squaring column against the dimensions to be amended, and to write new dimensions in the normal manner under the last dimension listed for that item.

Each dimension sheet should be headed with the contract number, and the abbreviated contract title, section of the job and the drawing number(s) to which the taking-off sheet referred at the head of each sheet. Each sheet should be numbered consecutively at the bottom. At the top of the first dimension sheet for each main section of works, the list of drawings from which the measurement is taken should be entered. Revisions to the drawing used should be precisely stated so that in the event of any change being made to work as originally planned it can be clearly seen what was measured in the BOQ.

Dimension sheets should be punched in the top left-hand corner on completion and fastened together with treasury tags. In many occasions, a dimension sheet comprises several works items all related to a single structure (e.g. foundation of structures). Under such situation, the quantities of each individual works item for this single structure should be properly highlighted to avoid transfer error. In some occasions, computer spreadsheet program is used to prepare the dimension sheet. Under such situation, it will be preferable for one dimension spreadsheet to contain a single works item only.

The assumption/methodology adopted in the taking-off exercise should be shown on the dimension sheets to facilitate subsequent cross-checking by more senior staff.

### *2.4.3 Drawings and information*

Taking off of dimensions should be based on the tender drawings, which should be registered in a drawing record showing the date of issue and of any revisions. Taking off drawings should be clearly marked, preferably by the use of a rubber stamp, stating “Drawing used in the preparation of Bills of Quantities”, as this will avoid any confusion as to what is included in the BOQ. Drawings should be marked to show that the works have been measured. Should revised tender drawings be issued for tender addendum purposes, all changes should be marked in red circles and the measured quantities should be adjusted for the changes, and incorporated in the revised BOQ. Queries should be raised and to be confirmed by the project engineer before making the necessary amendments.

## 2.5 TYPES OF BILLS OF QUANTITIES

There are different types of bills of quantities as listed below:

### *2.5.1 Trade bill of quantities*

Trade Bill is a bill of exchange issued and/or endorsed (accepted) by non-bank entities and which, therefore, can be discounted only at rates higher than the rate for bank bills.

In this case, the traditional bill of quantities is arranged in trade order. The order of trade is normally in the same order as the specification. It is usually used in building industry.

Apart from being arranged in trade order, each trade has the facility for each description to be priced and totaled to give the total cost of each trade. The total trade cost is then transferred to a general summary to obtain the total project cost.

In order to be able to refer to any section in the bill of quantities, each description is given a separate and distinct reference. It is also normal practice for each page to be numbered and labeled with the project name and trade.

### 2.5.2 Elemental bill of quantities

In this style, a bill of quantities is prepared in elemental format rather than the traditional trade order sequence. Elemental bills are divided in sections in accordance with the various main sections of the work. It is the most commonly used BOQ in SSIPs.

The disadvantage of the elemental bills is that the pricing of the Bills at tendering stage is complicated as the same item of work may appear in different sections of the bills. Thus there is unnecessary repetition of the same prices in different sections of the Bills, whilst the full extent of each item of work, which affects the prices considerably, can only be known by adding up the quantities for this item that appear in different sections of the Bills.

The advantage of this method is that the location of most items will be apparent by their position of the Bills of Quantities. This facilitates the administration of the contract on site (e.g. ordering materials, deciding the required number of operatives on site, preparing interim valuations etc.).

This BOQ can also be subdivided in to two: pre-construction BOQ and post- construction BOQ. The pre-construction BOQ is derived from Technical drawings whereas Post- construction BOQ is derived from As-built drawings thus includes variations, if any.

**Advantages of BOQ at pre contract phase:**

- Database - The pricing details within the BOQ provides a cost database for future estimating;
- Fee calculation - The BOQ provides an absolute basis for the calculation of consultants' fees;
- Asset management - The BOQ provides readily available data for asset management of the completed structure, life cycle costing studies, maintenance schedules, general insurance and insurance replacement costs;
- Taxation - BOQ provide a basis for quick and accurate preparation of depreciation schedules as part of a complete asset management plan for the project.

**Disadvantages of BOQ at pre contract phase:**

- Cost and time - The preparation of a BOQ tends to increase the cost and lengthen the documentation period;
- Estimating practice - Tenderer's may ignore the specification (e.g. workmanship requirements), pricing only according to the BOQ. This may lead to underpricing and the consequent risk of unsatisfactory performance as contractors try to avoid losing money;
- Procurement- The use of a detailed design and associated BOQ discourages contractors from submitting alternative design solutions, as alternatives will amend quantities. The BOQ is only suitable (if at all) to the traditional procurement system.

**Advantages of BOQ at post contract phase:**

- Certainty of progress payments - The BOQ provides a post-contract administration tool and becomes a basis for the evaluation of progress payments. The calculation of these progress claims is straightforward and reliable. This certainty offers contractor, principal and financiers peace of mind in the knowledge that all work is being carried out at prices fair and reasonable to all involved;
- Variation management - The BOQ provides a sound, common basis for the valuation of variations. Also, the prices for variations are reduced by the use of BOQ unit rates. Without a BOQ, the pricing of variations leads to more protracted negotiations;

- Risk management - The prices in the BOQ can be used as a basis for comparing a contractor's price with current trends in the marketplace. This provides a basis for management to determine the likely manifestation of risk factors;
- BOQ errors - Errors are not a major cause of variations. Choy (1991) found the average change order to be 7.7 percent of contract value with BOQ errors representing 4.5 percent of total variations.

**Disadvantages of BOQ at post contract phase:**

- BOQ errors - Because of the amount of detail required in a BOQ, there is a significant chance of finding errors, omissions and discrepancies between drawings and the BOQ, with consequent disputation. This risk of disputation arising from misinterpretation and error outweighs the advantages of BOQ;
- Unit rates - The cost data obtained from contactor-priced BOQ is often used by QSs for cost management, such as valuing interim valuations. This data can be suspect for reasons such as: contractors increase rates on early trades above their real cost, and reduce the cost of later trades, to improve cash flows; some contactors may load later trades to gain benefits from rise and fall;
- Responsibilities- BOQ involve a shift in, or "risk blurring" of, the contractor's responsibility that results in claims and disputes;
- Standard Method of Measurement- It is a tool designed to standardise the layout and contents and to provide a systematic structure of Bills of Quantities. It is often said that the SMM is much too complex and many disputes arise from its language and how it is interpreted by the contractor and QS. For details refer section 2.7.4).

### *2.5.3 Provisional bill of quantities*

This is a bill of quantities containing provisional quantities and issued to tenderers on the basis that the billed quantities will be adjusted during construction where they differ from the actual quantities. It is better to use this type when the drawings and specifications cannot be finalized prior to calling tenders.

### *2.5.4 Non-Specified bill of quantities*

As the name implies, this document contains only the items of work and their quantities as a stand-alone document separated from the specifications documents of these works.

### *2.5.5 Specified bill of quantities*

Here, the specifications are incorporated with the bill of quantities in the form of preamble notes and the bill of quantities description. The quantities do not normally form part of the contract but preambles and descriptions are part of the contract.

It is similar to the traditional BOQ but has the addition of a short type of specification included with each of the itemized materials and labor for each specific trade. Also at the beginning of the Specification Bill are clauses covering such things as:

- Notice to tenders
- General conditions of contract
- Preambles etc.

### 2.5.6 Builder's bill

This method is used by builders to obtain a quick guide or budget price. It is based on the price per square meter ($m^2$) of similar types of work completed by the builder and is used mainly in the Domestic Housing field.

A similar method using the cube basis that is the cubic meter ($m^3$) content of the building is used for the Commercial and Industrial field.

It must be emphasized that this method of calculation is used purely as a guide or budget price by the builder.

### 2.5.7 Operational bill of quantities

These are a tendering document for estimating costs prepared by designers that describes a construction project in terms of the operations (which include labor and plant) needed to build it.

**Advantages:**

- Separates the costs of labor, materials and plant thus enabling cost control;
- Increases the accuracy of estimating;
- Costs can be related to factors that directly determine them such as overall plant usage. Allows the reuse of information created in estimating for project management;
- Enables better estimation of variation in works.

**Disadvantages:**

- Bulky and costly to produce so increasing the work of the contractor's estimators;
- Radically changes the estimating process;
- Does not fit in with current contracts in regard to work variation;
- It needs computers to allow rapid manipulation of the data: this did not exist when it was originally proposed;
- The design team responsible for creating the operational bill need not be "very familiar with the build ability issues as they affect the construction process".

In general, the mostly used bill of quantities are the Elemental BOQ and the Trade Bills. However in engineering of water works, the most commonly used style of bills of quantities is Elemental BOQ.

An elemental bill of quantity must contain the following:

- The item number
- Description of items
- Item unit
- Item quantity of work against each

Bills of quantities consist of different parts of work items: General work items, Main work items and Contingencies. For example, general work items for SSI projects consist of all or part of the following list of items.

**Table 2-2: BOQ & cost estimate for general work items of Kebira SSI Project**

| Item No. | Description of Items | Unit | Qty. | Unit Rate | Total Amount |
|---|---|---|---|---|---|
| **Bill No1** | **General Works** | | | | |
| A.1 | Allow for mobilization of project construction | Sum | | | 50,000.00 |
| A.2 | Allow for costs of tests to be conducted elsewhere | Prov. Sum | | | 30,000.00 |
| A.3 | Allow for measures against nuisance from dust etc. | Month | | | 10,000.00 |
| A.4 | Allow for Contractors offices and labor and staff accommodation: Fixed cost | Sum | | | 150,000.00 |
| A.5 | Preparation of as-built drawings and site plan including operation and maintenance manual | Ls | 1 | | 30,000.00 |
| A.6 | Allow for Contractors plant yard workshop and stores: fixed cost | Sum | | | 50,000.00 |
| A.7 | Ditto: Running cost | Month | 6 | 2,000 | 12,000.00 |
| A.8 | Allow for medical arrangements: Fixed cost | Sum | | | 25,000.00 |
| A.9 | Ditto: Running cost | Month | | | 1,000.00 |
| A.10 | Progress photographs: Sets of negatives and 5 titled prints | Set | 10 | 500 | 5,000.00 |
| A.11 | Sign boards: Provisional | Prov. Sum | | | 3,000.00 |
| A.12 | Demobilization | Sum | | | 50,000.00 |
| | **Total of Bill No1 Carried to Summary** | | | | **416,000.00** |

Source: As adopted from Kebira SSI Project Design Report, ONRS, 2014

Note: The terms bill of quantities (BOQ) & bill of materials (BOM) are often confused or misused: bill of materials (BOM) should not be mistaken for bill of quantities (BOQ) since their definitions are different as follows: Bill of quantities (BOQ): is defined in previous articles. Whereas, Bill of materials (BOM): is a list of the raw materials, sub-assemblies, intermediate assemblies, sub-components, components, parts and the quantities of each needed to manufacture an end product. No physical dimension is described in a BOM. It may be used for communication between manufacturing partners, or confined to a single manufacturing plant.

## 2.6 PREPARATION OF BOQ

### *2.6.1 Preparation of bills of quantities in general*

Bills of quantities are prepared from drawings after computing take-off sheet for each and every part of structure by quantity surveyors and/or by designers as follow.

- The work of a project is usually divided into separate elements for payment purposes with respect to the kind of work involved, each element as a separate bill designated as a payment item;
- The bill of quantities is prepared by a “taking off” process in which the cost of structure is estimated from measurements in the Structural Engineer's drawings;
- Similar types of work are then brought together under one item, a process known as "abstracting";
- Then bill of quantities is arranged in a tabular form without completing columns of rate and amount;
- Finally, the total price of a bid is obtained by summation of the amounts for all items scheduled in the tender, arrived at by multiplying the estimated number of units for each item by the corresponding unit-price bid.

### *2.6.2 Measurements methods of area, volume & RF bar*

#### 2.6.2.1 Measurement of areas

Measurement of regular areas can be carried out by using the standard formulae shown in Appendix-II (PAH, 2016). Irregular areas may be measured by one of the following methods, and then checked independently using one of the two other methods:

- By planimeter or by direct measurement using the map scale.; or
- By dividing the area into a number of regular areas. The smaller the regular areas adjacent to the irregular outline, the greater the degree of accuracy; or
- By Simpson's Rule or Trapezoidal Rule. The smaller the interval between sections, the greater the degree of accuracy.

Where areas are measured by using a planimeter, the average of two readings should be taken, provided that the two readings do not differ by more than 12mm² when the average is less than 3,000mm², or 24mm² when the average is greater than 3,000mm², or in accordance with the instruction manual of the planimeter,. If the two readings differ by more than these limits, one or more check readings should be taken until two readings are obtained which satisfy these limits, and the average of these two readings should then be accepted.

#### 2.6.2.2 Measurement of volumes

Measurement of regular volumes can be carried out by using the standard formulae shown in Appendix III. Irregular volumes may be measured by one of the following methods, and then checked independently by using one of the four other methods:

- By dividing the volume into a number of regular volumes,
- By method of end areas,
- By Simpson's Rule to obtain the areas of contours,
- By Simpson's Rule to obtain the areas of equally spaced cross-sections, and
- By planimeter, either of above Simpson's Rule for contours or cross-sections.

When measurements of volumes require the use of contours or cross-sections, the spacing should be taken in accordance with the following table:

**Table 2-3: Spacing for Measurements of Volumes Require Contours or Cross-Sections**

| Type of Volume | Spacing |
|---|---|
| Bulk volume by contour | 5m |
| Bulk volume by cross-section | 10m |
| Volumes of roads, trenches and items with regular cross-sections over a given length | one at each change in direction or cross-section |

Source: PAH, 2016

It should be noted that if the position of cross-sections are altered, the volume will change. To avoid any problems of this nature that may occur when the works are re-measured on site, the measurement method adopted should be defined in a Particular Preamble to the BOQ, and the position of the cross-sections to be used should be marked on the contract drawings.

#### 2.6.2.3 Measurement of lengths and weights of RF Bar

Bar bending schedules should be prepared either manually in a schedule or by computer. However, they should never be incorporated into contract drawings. Specific requirements for scheduling and dimensioning of steel reinforcement are given in BS 8666 whilst the mass of the bars is calculated on the basis that steel has a density of 0.00785 kg/mm² per meter run. In the case of manually computed bar schedules the total lengths and weights of the various sizes and

types of bar should be summed on each sheet and transferred directly to abstract sheets. In the case of computerized bar schedules, the computed totals of weights of reinforcement bars should be transferred directly to the abstract sheets. In both cases, the schedule and computer print-out should, as for drawings, be clearly marked “Schedules used in the preparation of the BOQ.

### *2.6.3 Measurements at pre- and post- contract*

#### 2.6.3.1 General requirements

Measurement is not just about a quantity surveyor producing bill of quantities for contractors to price during tendering. The technique of measurement is used in both pre- and post-contract work, helping determine the likely cost of the works, and determining what contractors and subcontractors should be paid for work done.
Whereas, quantity surveying is a term or process used in the construction industry to take measurements of civil works, prepare specifications, and estimate the cost of works either for each piece of work or for the whole project.

Measurement of each designed activity both for permanent and temporary works should be accomplished in office to compute Engineer’s BOQ and project cost estimate based on working drawings. Such measurement should also be done at construction site on a regular basis to prepare payment certificate but should be based on as-built drawing. The followings are tasks to be mainly covered in quantity surveying:

- Taking measurements of civil works (Taking off quantities and preparing bill of quantities);
- Preparation of as-built specification;
- Preparation of approximate cost estimate at the very early stage of the project;
- Preparation of detail cost estimate at different stages (taking as-built measurements and preparing payment certificates or approval of payment certificates prepared by taking measurements);
- Determination of values of works (executed works) and preparation of payment certificates.

Measurement and valuation is clearly a prerequisite to certification and payment of works during construction. Most contracts are of the bill of quantities type (ad measurement contracts) and their measurement and valuation are governed by the conditions of contract. Supervising Consultant must carry out measurements of completed Works. A record of these measurements and derived quantities must be kept by both the contractor and the Supervising Consultant on site to form a basis for preparation of the Interim Payment Certificates.

The rules for measurement of each item are invariably described in IS–1200. However some of the general rules are listed below:

- Measurement shall be made for finished item of work and description of each item shall include materials, transport, labor, fabrication tools and plant and all types of overheads for finished the work in required shape, size and specification.
- In booking, the order shall be in sequence of length, breadth and height or thickness.
- All works shall be measured subject to the stated tolerances in Appendix-1.
- Same type of work under different conditions and nature shall be measured separately under separate items.
- The bill of quantities shall fully describe the materials, proportions, workmanships and accurately represent the work to be executed.

- In case of masonry (stone or brick) or structural concrete, the categories shall be measured separately and the heights shall be described as: From foundation to plinth level and from plinth to top of the structure.
- Quantities should be stated in the metric system and computed net from the drawings and no allowances made for bulking, shrinkage or waste. The methods of measurement, if a standard method is used, should be stated e.g. the UK Institution of Civil Engineer's "Standard Method of Measurement".
- Alternatively, a description of the method of measurement for each work item may be included in the Technical Specification. Clear definition is required to avoid disputes during execution of the contract.
- Quantities should be rounded up or down as appropriate to a logical degree of accuracy and spurious accuracy should be avoided.
- The following units of measurement and abbreviations are recommended for use.

**Table 2-4: Recommended units of measurement and abbreviations**

| Unit | Abbreviation | Remark | | Unit | Abbreviation | Remark |
|---|---|---|---|---|---|---|
| Meter | m | Linear measurement | | Kilogram | kg | |
| Square Meter | $m^2$ | Area | | Hour | h | |
| Cubic Meter | $m^3$ | Volume | | Month | mon | |
| Millimeter | mm | Linear measurement | | Week | wk | |
| Square Millimeter | $mm^2$ | Area of reinforcement | | Number | nr | |
| Hectare | ha | Larger area | | lump sum | LS | |
| Metric ton | t | | | | | |

### 2.6.3.2 Pre-contract measurement

During the early design stages, the quantity surveyor (or design engineer) measures the dimensions of the structure to produce a project budget estimates, perhaps based on benchmarking against similar structure or specific to the project site. As the design develops, the design engineer measures more detailed approximate quantities for cost planning purposes, ensuring that the design can be achieved within the budget. The quantity surveyor/ design engineer then measures the completed working drawings to produce a bill of quantities. Contractors then tender for the job by pricing the work described in the bill of quantities.

Measurements during Construction: Based on agreement made with the contractor, which is usually on monthly bases, measurements are made during construction for interim payments.

### 2.6.3.3 Post-contract measurement

Post-contract measurement is done by the two parties:

- By the quantity surveyor/supervisor for:
  - Cost control of the project;
  - Estimation of cost of variations to the work;
  - Calculate the value of nominated subcontractors' and suppliers' work;
  - Prepare interim valuations to pay the contractor for work done.
- By the contractor for:
  - Preparing the construction methodology;
  - Ordering goods and materials;
  - Procuring subcontract works;
  - Calculating the effects of any variations;

- Assess work done against the construction program;
- Make payments to subcontractors;
- Prepare or assessing valuations of work completed for interim payments.

#### 2.6.3.4 Responsible body for measurement

After a Contract is entered into, the Engineer i.e. supervisor for the Contract is responsible for discharging the measurement function and he may delegate his authority to the Engineer's Representative to carry out the measurement work with the assistance from the Survey Officer (or QS) and the site staff officially. Emphasis should be made to ensure a consistent and systematic approach throughout the pre- and post- contract stages and the need to implement an independent checking system for all the measurement works. The Engineer's Representative should also be responsible for coordinating measurement input from other professional staff such as the land surveyor. For record purposes, the persons preparing and checking the measurement should initial for all his work. The division of labour regarding the taking of measurements for a project varies under different circumstances and depends on:

- The nature and complexity of the works,
- The experience and availability of the staff members,
- The time within which the measurement is to be completed, and
- The standing instructions in the department.

### *2.6.4 Standard* method of measurement

#### 2.6.4.1 Purpose of SMM

Standardizing the method of preparing the BOQ and the units used in them is quite important to establish a considerable degree of consistence. To do this, a Standard Method of Measurement is used, the purpose of which can be summarized as follows (PAH, 2016):

- To facilitate pricing by standardizing the layout and content of the BOQ,
- To provide a systematic structure of bill items, leading to uniform itemization and descriptions,
- To provide a rational system of billing suitable for both manual and computer operation,
- To simplify the measurement of works and the administration of contracts,
- To provide a uniform basis for measuring works so as to avoid misunderstanding and ambiguities,
- To assist in the financial control of the works.

#### 2.6.4.2 Parts of standard method of measurement

The SMM is divided into five parts:

**Part-I**: gives general definitions of the terms used in the document;

**Part-II**: states the general principles of how to use the document and how item descriptions are built up;

**Part-III**: contains the rules for the preparation of the BOQ. It defines the sections into which the Bills are to be split, how items are to be grouped within these sections, and the units to be used. It also describes how amendments or amplifications to the SMM are to be dealt with;

**Part-IV**: is the General Preambles to the BOQ. This part provides information to the tenderer to price the items, and must be reproduced in the BOQ;

**Part-V**: is the units and method of measurement and is divided into sections. Each section details:

- The items to be measured;
- The units of the measurements;
- The method of measurement of each item;
- The wording for the build-up of descriptions, and
- An item coverage for the relevant item of work listing the matters which are deemed to be included in that item, enabling the contractor to price the item fully.

### *2.6.5 Engineering tolerance*

#### 2.6.5.1 Background

Dimensions should be as accurate as possible, but it should be noted that they should not be recorded to a degree of accuracy which is greater than that to which the works can be executed, or greater than that to which the actual measurement is made, which we call it tolerance. When measurements are taken from drawings, specified dimensions on the drawings should always be used whenever possible. When measurements of the works are made on site, they shall be recorded to the smallest division on the appropriate measuring instrument used to record to a degree of accuracy, which is not less than that to which the works are to be executed.

If we leave such dimension without a tolerance, no one else knows its importance, or the unimportance of that dimension. Not only can a lack of tolerances lead to improper fits, it will also add to delays and higher costs, as it may led to revision as per the market condition. Thus, engineering tolerance or simply tolerance is the permissible limit or limits of variation in:

- A physical dimension,
- A measured value of physical property of a material, manufactured object, system, or service,
- In other measured values (such as temperature, humidity, etc.),
- In engineering and safety, a physical distance or space (tolerance), as in a truck (lorry), train or boat under a bridge as well as a train in a tunnel,
- In mechanical engineering the space between a bolt and a nut or a hole, etc.

Dimensions, properties, or conditions may have some variation without significantly affecting functioning of systems, machines, structures, etc. Such variation beyond the tolerance (for example, a temperature that is too hot or too cold) is said to be noncompliant, rejected, or exceeding the tolerance.

Refer Appendix-1, for detailed values of tolerance limits of different materials on construction site.

#### 2.6.5.2 Considerations when setting tolerances

A good set of engineering tolerances in a specification, by itself, does not imply that compliance with those tolerances will be achieved. Actual production of any product (or operation of any system) thus involves some inherent variation of input and output. Measurement error and statistical uncertainty are also present in all measurements. With a normal distribution, the tails of measured values may extend well beyond plus and minus three standard deviations from the process average. Appreciable portions of one (or both) tails might extend beyond the specified tolerance.

The process capability of systems, materials, and products needs to be compatible with the specified engineering tolerances. Process controls must be in place and an effective Quality management system, such as Total Quality Management, needs to keep actual production within the desired tolerances. A process capability index is used to indicate the relationship between tolerances and actual measured production.

The choice of tolerances is also affected by the intended statistical sampling plan and its characteristics such as the Acceptable Quality Level. This relates to the question of whether tolerances must be extremely rigid (high confidence in 100% conformance) or whether some small percentage of being out-of-tolerance may sometimes be acceptable.

#### 2.6.5.3 Difference between Tolerance and Allowance

As per www.quora.com, “Tolerance is the limit of random (unintentional) deviation of a dimension from its nominal value. Allowance is the amount of designed (intentional) deviation between two mating dimensions in a fit, which, in combination with their respective tolerances, results into a maximum and minimum clearance or interference.”

## 2.7 FINAL STAGES FOR THE PREPARATION OF BOQ

### *2.7.1 General*

After the dimensions have been taken off, final stages leading to the preparation of the BOQ are required as presented in following sections (PAH, 2016).

### *2.7.2 Squaring*

The term ‘squaring the dimensions’ refers to the calculation of the numbers, lengths, areas or volumes and their entry in the third or squaring column on the dimension paper as mentioned under section “Taking off”. Squaring should be carried out to three decimal places, with the final squared quantities rounded off accordingly.

Squaring must be independently checked to eliminate errors. Any incorrect figures should be neatly crossed out in red ink or ball pen and the correct figures written above the incorrect ones. Correcting fluid shall not be used nor shall incorrect figures be erased. All squared dimensions and waste calculations should be ticked in red ink or ball pen on checking and any alterations should be made in a similar manner. Amended figures must be further checked. Staff responsible for checking the dimension sheets shall also conduct their checks with reference to the design drawings and check the assumption/methodology stated on the dimension sheets.

### *2.7.3 Abstracting*

Abstracting is the process whereby the squared dimensions are transferred to an abstract sheet or other similar computerized formats, where they are written in a recognized order, ready for billing, under the appropriate section headings, and are subsequently reduced to the recognized units of measurement in readiness for transfer to the bills.

As each item is transferred to the abstract, the description of the appropriate dimension should be crossed through with a vertical line on the dimension sheet, with short horizontal lines at each end of the vertical line, so that there is no doubt as to what has been transferred.

Each abstract sheet should be headed with the contract number, abbreviated contract title, sheet number and section of the works to which the abstracted dimensions refer. The section headings normally should follow those given in the SMM, in the same order. Entries in the abstract should be well spaced. The items should be entered in the same order as they will appear in the bill, since the primary function of the abstracting is to classify and group the various items preparatory to billing, and to reduce the dimensions to the recognized unit of measurement.

Descriptions should be spread over two columns, with a line drawn underneath, and the appropriate dimensions listed below in the first column, with any deductions in the second column. Against each dimension, the number of the dimension sheet from which that dimension has been transferred should be inserted in brackets, for easy cross-referencing. When the total quantity for each item is calculated, any deductions from the second column, which have been taken into account in arriving at the total quantity, should then be lined through to ensure that they are not deducted twice.

It is a good practice to precede each description in the abstract with the prefix C, S, L or Nr denoting that the item is cubic, square, linear or enumerated to reduce the risk of errors arising with regard to units or quantities. The order of items in each section of the abstract should, as much as possible, be standardized. It is usual to adopt the order of cubic, square, linear and finally enumerated items, with smaller items preceding larger ones, and cheaper items preceding more expensive ones in each group, but attention should also be paid to the sequence of items in the SMM. Where it is necessary to abstract a number of similar items, but of different sizes, these should be grouped under a single heading with each size entered in a different column.

On completing the entry of all items on the abstract, all entries must be checked, columns of figures cast, deductions made, totals reduced, and all the latter work checked and ticked in red ink or ball pen in the same procedure as described for squaring.

### *2.7.4 Billing*

Billing is the final stage in the bill preparation process in which the items and their associated quantities are transferred from the abstract onto the standard billing sheets or other similar computerized formats that are in a format that enables the tenderer to price each item and arrive at a total tender sum. As each item is transferred to the bill, it should be lined through on the abstract to prevent any risk of errors occurring during the transfer stage.

Generally, all quantities transferred are to be billed to the nearest whole unit. Fractional quantities are not generally necessary but, where required, should not be given to more than one place of decimals. The order of billed items should be the same as in the abstract, and they should be grouped under suitable section headings as they appear in the SMM. Items should be indexed, either by a letter or a number, in the first column of the billing sheet. The total sum on each page should be carried to a collection or summary for each section, and the totals from these carried to a Grand Summary, the total of which constitutes the tender sum.

Unless for those abbreviations as defined in the SMM, abbreviations must not be used in the descriptions and the wording and layout of each description must follow the rules laid down in the SMM and its amendments in the Particular Preambles. On completion, the draft bill must be carefully checked against the abstract, and the abstract suitably marked in red ink or ball pen as each item is dealt with. Particular care should be taken to ensure that all the quantities, units and descriptions are correct, and that the sequence of items, the section headings and sub-headings, and the transfer of totals to collection and summary, are satisfactory and adequately covered. To minimize the occurrence of missing items, a standard checklist showing typical types of BOQ items included in different major categories of works (such as headworks, drainage works, land formation, geotechnical works) can be developed so that the staff responsible for checking of the draft bill can carry out consistency check on the bills against such standard checklist. Finally, a further check should be carried out once the bill is typed.

## 2.8 BILL OF QUANTITY AS A TOOL FOR CONSTRUCTION

BOQs are various tasks or works itemized sequentially that are to be undertaken during construction and as described on the drawings and in the specifications. It is thus the tool for valuing of the work done as it is the sum of all of the various quantities of work done multiplied by their respective unit rates. Bill of Quantity can either be estimated from working drawings or spread sheet/take-off-sheet or both.

In general, in-spite of the fact that prices variation could be accepted to certain level due to variation of prevailing inter-related conditions like BOQ and rates, linked to each and every scheme and location (e.g. Total command area, reservoir capacity, and cost of construction materials, and geological formations etc. ...). Evidences show that variations are far beyond acceptable level due to either under estimating the quantity or missing items of works in the BOQ table, though it is critically required in the bills.

This fact is threatening future motives of accelerating irrigation development and improving food security. Moreover, there are big variations between the engineering estimates, contract prices and actual investment costs. Thus, it needs to estimate accurately the BOQ and rates of various tasks or works of a particular project.

The Bills of Quantities can serve a number of functions, such as:

- A basis for measure of the value of work completed for interim payments.
- A breakdown of the tendered price, with no contractual status, but providing information for the selection from tenderers.
- An estimate measure of the work for the tendered price, to be used to arrive at a revised contract price once the actual quantities of work carried out are measured. This is the re-measure form of contract.
- A schedule of rates as the contract basis for valuing variations in the work.

## 2.9 ESTIMATION OF BILLS OF QUANTITIES

### *2.9.1 Pre-requisites for estimation of BOQ*

Upon the completion of design aspects of a project, its drawings showing the various components of an irrigation and related infrastructure system are to be prepared. Consequently, estimated costs of construction of irrigation projects, which are usually considered as the engineers estimate, will be prepared and presented based on three particulars: namely, the established design criteria of that project, prepared bills of quantities and estimated up-to-date rates for construction materials and procurements of items.

### *2.9.2 Provisional sums*

A general provision for physical contingencies (e.g. quantity overruns) may be made by including a provisional sum in the Summary Bill of Quantities (or Summary Activity Schedule). Similarly, a contingency allowance for possible price increases should be provided as a provisional sum in the Summary Bill of Quantities (or Summary Activity Schedule). The inclusion of such provisional sums often facilitates budgetary approval by avoiding the need to request periodic supplementary approvals as the future need arises. Where such provisional sums or contingency allowances are used, the Special Conditions of Contract should state the manner in which they will be used, and under whose authority.

To provide payment to the Contractor for providing administration, facilities, amenities, attendance, etc., each related provisional sum should be accompanied by an item in the Bill of Quantities (or Activity Schedule) for the Bidders to quote agreed sum or a percentage fee for services to be provided.

### *2.9.3 Monthly interim payments due to the contractor*

An agreed and accepted method would be established with the Contractor for carrying out the necessary measurements, calculations and certifications required for interim payments in accordance with guidelines previously agreed with.

At monthly intervals, the contractor must submit to the Supervising Consultant a statement or valuation based on the agreed measurements. The valuation must show the estimated value of the measured works executed up to the end of the previous period as well as the estimated value of work completed during the month in question. The valuation once checked and amended by the Supervising Consultant, where necessary, is used by the Supervising Consultant to prepare the Interim Payment Certificate. When the Contractor will submit his payment applications with all the measurements, costing calculations and supporting documentation to the Consultant, then the Consultant will review, check and verify the application on the basis of the documentation submitted and site inspection records. During the review, the Contractor's statements will be checked in respect of quantities, rates, extensions and additions. Interim Payment Certificates are useful in maintaining liquidity for the contractor. Therefore, the Supervising Consultant must not unnecessarily reject whole sections of works claimed by the Contractor, but make amendments for unsatisfactory works. Liquidated small scale irrigation project, where applicable, will be deducted from the payment in accordance with the procedures set in the Works Contract Document.

Work Items having an agreed unit rate will be processed in accordance with the volume of work executed and the agreed unit rate. For Work items where the method of payment is set on a Lump Sum basis, the payment will be dealt in accordance with the volume of work executed within that payment period measured and estimated as a percentage of the total volume of work described in the Contract document.

The Resident Engineer will ensure that the Contractor submits his proposals for any work under the Variation Order that cannot be ascertained from the priced BOQ. He/she will examine and amend, should there be a necessity for such actions, the rates and prices proposed by the Contractor to fairly represent the cost of such works. These rates will not necessarily be the rates that will be fixed by the Engineer, but may be termed as Temporary Rates, which could be used for the purpose of interim valuations pending the fixing of rates by the Engineer in consultation with the contractor.

After verifying the sufficiency of the documentation and accuracy of calculations, Interim Payment Certificates will be prepared within seven (7) days of receiving the application and issued to the Client for the processing (For details refer, “Part-IV, GL-2 Construction Supervision”).

### *2.9.4 Payments follow up*

After submission of Interim Payment to, the Consultant will monitor the payment process and alert the Client when payment delays accrue to the point when:

- Interest charges will become due, and

- The Client will be in default for late payment

### *2.9.5 Estimation of BOQ*

Bill of quantities of each work item should be estimated based upon take-off-sheet for each and every surface of each structure or work item.

The tender BOQ is accordingly only an estimate of the work to be done. Occasionally, the BOQ may be inaccurate if there has been insufficient survey and investigation undertaken during the design stage or if the quantities are estimated rather than calculated or if there are unforeseen variations.

The result of this is that the final quantities of the items of work will be greater/less than the tender quantities, and hence contract price. The final contract value is, accordingly, calculated on the actual volumes of work undertaken from as-built drawing.

Variations of this nature are usually small and accommodated by means of the inclusion of a contingency allowance in the BOQ. Such contingencies are normally in the order of five to ten percent of the contract price and are formally "included" in the contract by the measurement of works undertaken. Thus in this case, no other correspondence or paperwork is necessary.

If the variations are significant it may be necessary to review the works to be undertaken or to increase the funds allocated to the project via some documentation.

***Box 2-1:***
***Worked Example-1****: Consider the following given design table & drawing of drop structure of Melewe Irrigation Project located in SNNPRS. Based on these given data, prepare consistent take-off-sheet and hence corresponding bills of quantities. The foundation condition was investigated and found out that it is amalgamated fractures of rock and gravel majority of which is a mixture of sandy clay soil.*

**Table 2-5: Design data for TOS & BOQ estimation (Drop structure on LMC @2+420.0)**

| SN | Description | Symbol | LMC | Remark |
|---|---|---|---|---|
| 1 | **Design Data** | | | |
| | Chainage (m) | Chainage | 2+420.0 m | |
| | Discharge (m3/s) | Q | 0.2 $m^3/s$ | |
| | Upstream bed level (m) | u/s CBL | 2381.0 m | |
| | Downstream bed level (m) | D/s CBL | 2380.0 m | |
| | Upstream Full Supply level (m) | U/S FSL | 2381.46 m | |
| | D/s Full Supply Level (m) | D/S FSL | 2380.5 m | **As adopted from MC Profile & cross section** |
| | Upstream freeboard (m) | U/S FB | 0.3 m | |
| | Downstream freeboard (m) | D/S FB | 0.3 m | |
| | Upstream Top Bank Level (m) | U/S TBL | 2,381.76 | |
| | D/s Top Bank Level (m) | D/s TBL | 2,380.76 | |
| | Upstream water depth (m) | U/S D1 | 0.4 m | |
| | Downstream water depth (m) | D/S D2 | 0.4 m | |
| | Upstream total depth (m) | U/S D | 0.73 | |
| | Downstream total depth (m) | D/S D | 0.73 | |
| | Drop height (m) | Z | 1.00 | |
| | Upstream Bed Width (m) | U/S BW | 0.5 m | |
| | Downstream Bed Width (m) | D/S BW | 0.5 m | |

| SN | Description | Symbol | LMC | Remark |
|---|---|---|---|---|
| 2 | **Critical flow hydraulics** | | | |
| | Drop width (m) | bc=0.734*Q/($h_1^{1.5}$) | 0.51 | |
| | Drop width (m) | adopted same as canal bed width | 0.50 | |
| | Unit discharge (m3/s/m) | q=Q/$b_c$ | 0.38 | |
| | Critical depth (m) | dc= ($q^2$/g)$^{1/3}$ | 0.25 | |
| 3 | **Stilling basin** | | | |
| | Basin width (m) | Wb =18.46*$Q^{0.5}$/(Q+9.91) | 0.80 | |
| | Basin width | adopted Wb | 1.00 | |
| | Lip height | a=dc/2 | 0.12 | |
| | | adopted | 0.15 | |
| | Basin Length | L = (2.5+1.1dc/z+0.7(dc/z)$^3$)*(z*dc)$^{1/2}$ | 1.38 | |
| | | adopted Lb | 1.50 | |
| 4 | **Transition** | | | |
| | Upstream | L1 = 3*$h_1$ | 1.28 | |
| | | adopted | 1.30 | |
| | Downstream | L2 = 4*$h_2$ | 1.70 | |
| | | adopted | 1.80 | |

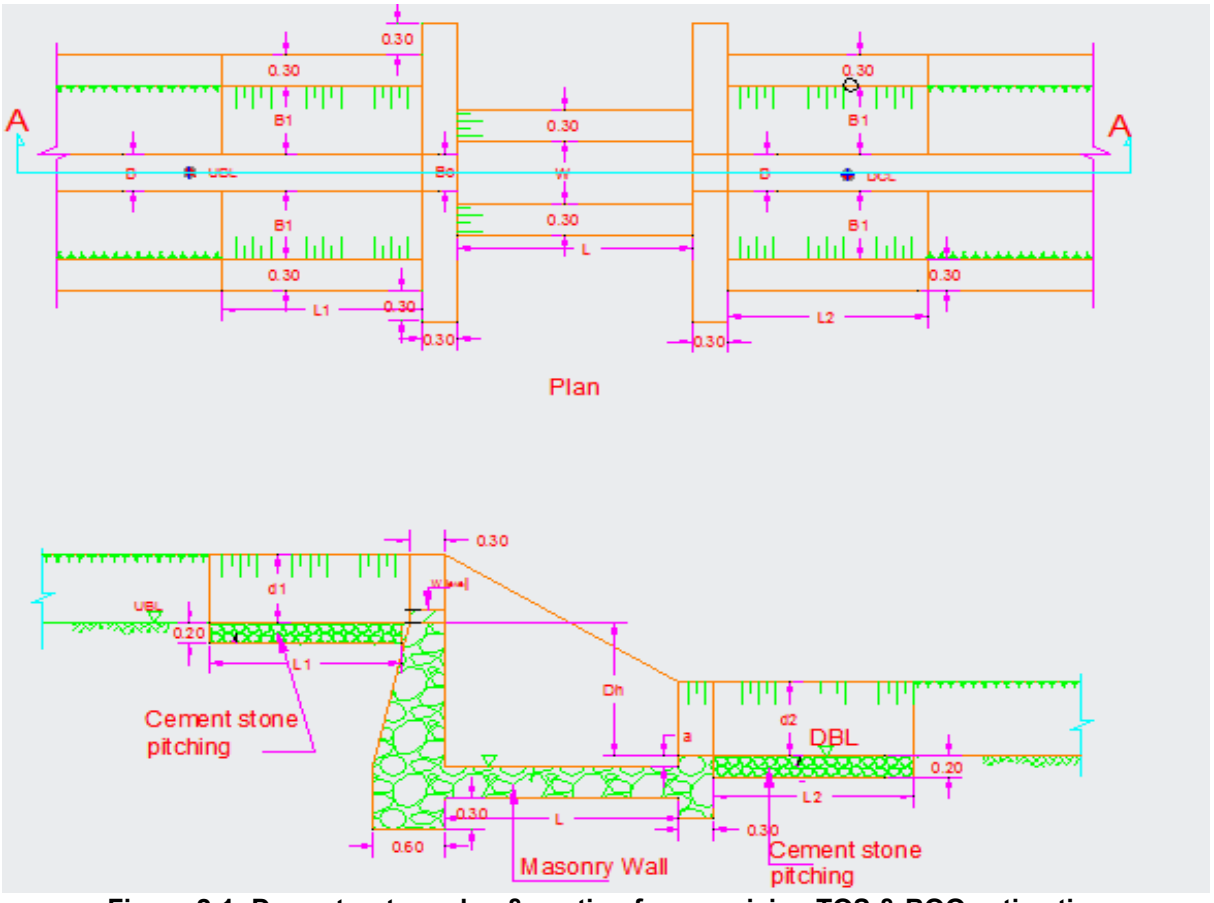


**Figure 2-1: Drop structure plan & section for exercising TOS & BOQ estimation**

***Solution**: The take-off-sheet* Format *need to be prepared for each and every component of the structure and corresponding bills of quantities need to be summarized as follow.*

**Table 2-6: Detailed TOS for the drop structure on LMC @2+420.0**

| SN | Item Description | Unit | Qty. | Width, b (m) | Length, L (m) | Height, h (m) | Volume/Area ($m^3$) |
|---|---|---|---|---|---|---|---|
| 1 | **Drop of 1.0m height on LMC @2+420.0** | | | | | | |
| 1.1 | Site clearance, grabbing and removal of top soil to a max. depth of 15 cm | m2 | 1 | 3.88 | 5.20 | - | 20.15 |
| **1.2** | **Soil Excavation to required depth** | **m3** | | | | | **17.03** |
| 1.2.1 | For u/s protection | m3 | 1 | 3.28 | 1.3 | 0.93 | 3.94 |
| 1.2.2 | For stilling basin | m3 | 1 | 1.60 | 2.1 | 1.60 | 5.38 |
| 1.2.3 | For D/s protection | m3 | 1 | 3.28 | 1.8 | 0.93 | 5.45 |
| 1.2.4 | For U/s Footing | m3 | 1 | 3.88 | 0.6 | 0.7 | 1.69 |
| 1.2.5 | For D/s Footing | m3 | 1 | 3.88 | 0.3 | 0.5 | 0.58 |
| **1.3** | **Backfill and compaction** | **m3** | **1** | | | | **14.05** |
| 1.3.1 | For u/s protection | m3 | 1 | 0.3 | 1.3 | 0.93 | 0.36 |
| 1.3.2 | For stilling basin | m3 | 1 | 1.60 | 2.10 | 1.60 | 5.38 |
| 1.3.3 | For D/s protection | m3 | 1 | 3.28 | 1.8 | 0.93 | 5.45 |
| 1.3.4 | For U/s wings | m3 | 2 | 1.49 | 0.3 | 2.03 | 1.81 |
| 1.3.5 | For D/s wings | m3 | 2 | 1.49 | 0.3 | 1.18 | 1.05 |
| **1.4** | **Masonry works** | **m3** | | | | | **5.21** |
| 1.4.1 | For vertical drop | m3 | 1 | 1.60 | 0.45 | 1.30 | 0.94 |
| 1.4.2 | For u/s & d/s vertical wings | m3 | 4 | 1.7 | 0.3 | 0.73 | 1.47 |
| 1.4.3 | For inclined wings | m3 | 2 | 0.3 | 1.50 | 1.3 | 1.17 |
| 1.4.4 | For stilling basin | m3 | 1 | 1.60 | 1.50 | 0.3 | 0.72 |
| 1.4.5 | For Footing u/s | m3 | 1 | 0.60 | 2.1 | 0.7 | 0.91 |
| 1.4.6 | For Footing d/s | m3 | 1 | 0.30 | 2.1 | 0.5 | 0.32 |
| **1.5** | **Dry Stone pitching for transition** | **m3** | | | | | **2.87** |
| 1.5.1 | For u/s protection base | m3 | 1 | 0.50 | 1.3 | 0.2 | 0.13 |
| 1.5.2 | For d/s protection base | m3 | 1 | 3.88 | 1.8 | 0.2 | 1.40 |
| 1.5.3 | For u/s protection side walls | m3 | 2 | 1.1 | 1.3 | 0.2 | 0.57 |
| 1.5.4 | For d/s protection side walls | m3 | 2 | 1.1 | 1.8 | 0.2 | 0.78 |
| **1.6** | **Plastering internal & top faces of side walls** | **m2** | | | | | **12.19** |
| 1.6.1 | For vertical drop face | m2 | 1 | 1.0 | | 1.0 | 1.00 |
| 1.6.2 | For u/s & d/s vertical wings & top faces | m2 | 4 | 1.7 | | 0.73 | 4.89 |
| 1.6.3 | For inclined wings & top faces | m2 | 2 | 1.5 | | 1.60 | 4.80 |
| 1.6.4 | For stilling basin | m2 | 1 | 1.0 | | 1.5 | 1.50 |
| **1.7** | **Pointing external faces of side walls** | **m2** | | | | | **9.80** |
| 1.7.1 | For u/s & d/s vertical wings outer faces | m2 | 4 | 1.14 | | 1.73 | 7.85 |
| 1.7.2 | For inclined wings outer faces | m2 | 1 | 1.5 | | 1.30 | 1.95 |

**Table 2-7: Detailed priced BOQ for the drop structure on LMC @2+420.0**

| SN | Description | Unit | Qty. | Unit rate (ETB) | Total cost (ETB) |
|---|---|---|---|---|---|
| 1 | **Drop of 1.0m height on LMC @2+420.0** | | | | |
| 1.1 | Site clearance and removal of top soil to a max. depth of 15 cm | m2 | 20.2 | 8 | 161 |
| 1.2 | Earth Work in excavation including all lead and lifts in all type of soils complete in all respect. | m3 | 17.0 | 110 | 1,874 |
| 1.3 | Backfill and compaction | m3 | 14.0 | 132 | 1,854 |
| 1.4 | Stone masonry in 1:4 cement sand mortar complete in all respect including all lifts. | m3 | 5.2 | 1,200 | 6,249 |
| 1.5 | Dry Stone pitching for transition | m3 | 2.9 | 309 | 888 |

| SN | Description | Unit | Qty. | Unit rate (ETB) | Total cost (ETB) |
|---|---|---|---|---|---|
| 1.6 | Plastering internal & top faces of side walls | m2 | 12.19 | 168 | 2,049 |
| 1.7 | Pointing external faces of side walls | m2 | 9.80 | 124 | 1,215 |
| | **Total cost for Drop Structure on LMC @2+420.0** | | | | **14,290** |

# 3 UNIT RATE ANALYSIS

## 3.1 PURPOSE OF ANALYSIS OF RATES

Analysis of rate is the method of arriving at a probable cost per unit quantity of work or supply in accordance to its specification including cost of required materials, labor, transportation, equipment, etc. based on the prevailing rates.

But with ever increasing dynamic deviations in variables of construction industry, parameters of construction materials alter to the fastest rate as well. Consequently, it needs to establish new rates for each bill items of works of irrigation projects depending on location, duration and quality/performance of work that the project is insisting on.

This rate build up should be made for all bill items of works considering up-to-date material cost and approximating future inflation of input construction items. Based on these costs, annual maintenance and operation costs shall be derived for budgetary purposes and financial and economic evaluation. Thus, the purposes of analysis of these rates are:

- To work out the actual cost per unit of the items of works.
- To work out the economical use of materials and processes in completing the particulars item of works.
- To work out cost of extra items of works which are not provided in the contract bond, but are to be done as per the directions of the client.
- To revise the schedule of rates due to increase in the cost of material and labour or due to change in technique. Thus, unit rates in the bills are the basis for the valuation of any variations to the design

## 3.2 FACTORS AFFECTING RATE OF A PARTICULAR ITEM OF WORKS

### *3.2.1 General*

In order to determine the rate of a particular item of works, the factors affecting the rate of that item of works should be studied carefully and then finally a rate is decided for that item based on the identified elements. This process of determining the rates of an item of works is termed as analysis of rates or rate analysis.

### *3.2.2 Work norms*

**General**: Rates related to productivity of daily labourers and quality of construction materials (e.g. mix ratio and material quality & model, etc.) need to be fixed with regard to our countries standard references and thus shall be considered for different work norms for example, for daily labourers we can work for Day work, Piecework or Task work.

***Day-work:*** is the work done on daily basis, thus meant simply that a worker is paid a fixed amount of money for being present on a site for a full working hours of a day, which is usually eight hours of work. Here, the amount of work produced depends entirely on the supervisor's ability to encourage the worker, and the worker's own motivation and sense of responsibility. In many circumstances this can lead to very low productivity, especially with permanent staffs who have no particular incentive to work hard as they know they will be paid (generally very poorly) whether they work or not. Such workforces are known as daily-workers.

***Piece-work:*** In this case, the worker is allocated an amount of work for an agreed rate of pay. The work they do is measured and paid accordingly based on volume of work done. Thus, the more they do the more they are paid. This approach can give very high productivities, but it can also result in exploitation, especially when the rate for the work is too low. Casual workers are seldom in a good position to negotiate favorable rates under this work method. The most dangerous situation is when workers have to put in very long hours to achieve even a subsistence rate of pay. This is a method of setting work, usually preferred by the private sectors.

***Task work:*** is evolved on projects where the workers were subjected to government regulations, which is meant they could not be paid more than the prevailing government wage for a day's work. Instead some other incentive had to be provided. Setting a realistic task, or amount of work to be completed for the day, meant that workers could work as hard as they wanted and then go home to do other things. Tasks are generally set to be achievable in 70 percent of the working day (a working day being assumed as a period of eight hours), but are often completed in 50 per cent of the working day (i.e. in four hours). This approach has proved very successful in practice, often doubling the amount of work achieved in a day; and by inference doubling the productivity of the individual worker, as well as halving the costs.

***Group-work***: There is also a variation of the individual task demanding group task, where work is set for groups of people rather than for individuals. This is done where the nature of the work requires the cooperation of a team, such as excavating and loading material into trucks or trailers. There is no basic difference in the concept, and task quantities are usually a simple multiple of the individual tasks making up the group.

Here is a typical work output norm obtained from World Bank study for excavation of medium hardness soil as the baseline to selection of work methodology for this study.

**Table 3-1: Typical excavation work output norms**

| S/N | Payment Method | Countries Experience with labour based technology ($m^3$/d) | |
|---|---|---|---|
| | | New approach | Long tradition |
| 1 | Daily paid | 0.88 to 2.62 | 1.75 to 5.25 |
| 2 | Task work | 1.75 to 5.25 | 3.50 to 8.75 |
| 3 | Piecework | 3.50 to 10.5 | 7.00 to 14.0 |

Source: The World Bank Study, Coukis et al, 1983. Op. Cit., page 180, Table 7-7.

### *3.2.3 Additional factors affecting rate of works*

In addition to the above mentioned factors, we need to consider the following while establishing rate of a particular item of work:

- Cost and specifications of materials of construction works (such as cement, sand, gravel, stone, plywood, formwork, water, soil for fill works, mesh wire, gabion, corrugated iron sheet (CIS), pipes of different size, etc.) and their quality, proportion and constructional operation method,
- Motivation and experience of the workforce,
- Organization of the work /field experience or practice/,
- Type and condition of tools and equipment provided to the workers,
- Quantity of materials and their costs at the project site,
- Cost of laborers and their wages at the project site,
- Location of site of work and the distances from source and conveyance charges,

- Overhead and establishment charges (such as contingencies to cover the cost of unforeseen expenditure that may be required during the process of the execution, of up to 20% of capital investment cost is added to cover it),
- Estimated profit margin (of up to 15% of capital investment cost is added to cover it).
- In general, a sum of profit margin and overhead cost of not more than 30% shall be added to capital investment cost of the project.

## 3.3 CONSIDERATIONS IN RATE ESTABLISHMENT

In this analysis, we have to consider rates to constitute at least five different components:

- **Direct cost of materials**: These include procurement of construction materials and its transportation cost to the project site;
- **Labor cost**: These include cost of excavation, back filling, compaction, concrete mixing, pipe laying i.e. assistance to pipe fitters by carrying and placing pipes and fittings in position, curing, assistance to masons, loading and unloading, etc.
- **Equipment, Tools and Machinery rental cost**: These include tools & machineries used to execute that particular activity, either rental and/or procurement;
- **Transportation cost:** This include delivering cost of construction material in to the project site and away from the project site such as disposing of extra over.
- **Utilization Factor/Productivity Norms**: These parameters are very important especially to produce a unit rate of each activity.

## 3.4 CONSIDERATIONS OF INPUT COMPONENTS OF CONSTRUCTION MATERIALS

### *3.4.1 Direct cost of material*

This cost need to include such cost as unit direct procurement cost of material at project area of the client as well as unit transportation cost of that material from supply sources to these stations. This unit cost of material is subsequently used in analysis of rate of corresponding item of work.

### *3.4.2 Labour cost*

In this component, incorporate such costs like:

- Skilled/professionals and assistant professionals/ salary and other benefits such as insurance, transportation allowance and the like and
- Unskilled or daily labourers cost /mason, bar bender, carpenter etc. /.

### *3.4.3 Equipment*

This component shall include under the assumption that the client will use machineries and equipment for head works excavation at rental or procurement base. If no machineries are used, rate computed for daily labourers can be adopted however it will be time consuming and ineffective.

In general, price of output of any water resources development project construction activity is a function of the following four factors:

- **Direct inputs**: These include materials, labour, energy, etc. Direct inputs generally vary in proportion to output.
- **Indirect inputs and overheads**: These include depreciation, administrative expenses, etc. These are generally fixed and do not vary directly with the volume of output.

- **Productivity**: Refers to the efficiency with which inputs are converted into outputs (e.g. through new technical solutions, increased labour productivity, or more effective organisation of work).
- **Profit**: Is a residual determined by the sales price, and combinations of the three preceding items. Profit varies widely and may be negative under worst case.

The output price may change for any one or more of the following reasons for any construction project:

- Widening or narrowing of profit margins due to changes in market conditions (i.e. irrespective of changes in costs);
- Increases or decreases in the prices of direct inputs; and
- Changes in productivity resulting in changes in the quantity of direct inputs per unit of output.

The rate established in this Guideline includes both labour and machinery- based categories. The assumption is that major works in irrigation head-works and structures and pipe lying of say over 6″ diameter are implemented on machinery-based whereas spring development works and pipe lying of up to 4″ diameter are labour based.

## 3.5 ESTABLISHING UNIT RATES

### *3.5.1 Assumptions*

There is no definite state of input parameters to be adopted for the analysis of rates, because it is dependent on the actual condition of the area at that moment. Consequently, unit rate of all the mentioned items of activities above has to be standardized depending on the following assumptions and considerations.

- It is a fact that soil layers get stronger and stiffer as we go down along a specific section of soil. In addition, soils of different nature also vary in strength from place to place even at the same level. The reality is thus, deeper layers are harder and require more vertical lift. Accordingly earth works under such condition varies from layer to layer, place to place and from saturation conditions of soil. Consequently, excavation of soil is worked out both for extreme conditions and disposal for different ranges of haulage distance. On the other hand, excavation in ordinary soil itself varies depending on types of excavation such as pit, trench and bulk excavations. Thus average standard outputs are to be considered for these different conditions.
- Output of each unskilled/daily labourer, mason, etc./ on such works as excavation, masonry, concrete and the like, differs from person to person and even the same person from day to day depending on his/her capability and comfort-ability. Thus, an average condition has been assumed to estimate rate of each of these works.
- For certain applications, such as construction of canal linings and curved surfaces, concrete may be applied by the shotcrete method. In shotcreting, concrete is sprayed under pneumatic pressure rather than placed between forms. Often the use of shotcrete eliminates the need for formwork and permits placement of concrete in confined areas where conventional forms would be difficult or impossible to construct. However, in this analysis concrete with formworks is considered assuming the work is of small scale. In fact, both vibrator and manual approach have been considered for concrete mixing.
- Rates of each of the considered activities are based on the principle of input-output relation through processing, where output is the rate to be established depending on dynamically variable market condition of input. Whereas, input parameters are unit purchase and transportation cost and the process is our analysis.

- Computed unit rates shall be compared and analysed based on existing experiences and data collected from latest studies and water works contracted out by Ministry of Water Resources and other NGOs.
- The direct unit costs of labour and equipment employed in the execution of items of works/activities to be established in bill of quantities is a function of degree/quality of performance of the worker/operator and the machine itself. Thus, corresponding rate varies accordingly and hence the analysed rate is dependent on average condition that one can do under normal condition.
- Input from professional staffs and their assistants are incorporated in unit rate analysis in such a way that their contribution in each item of work is subdivided in to possible items of work that can be implemented in parallel i.e. possible work item they can supervise.
- The established work output norms per day are to be based typically on standard working hours of 8 hours per day. However, in case some benefits are endorsed, workers would be encouraged definitely, which as a result leads to improvement of the norms more than what has been pointed-out in our analysis.
- Daily labourers are expected to participate on such item of work like excavation, back filling, compaction, concrete mixing, pipe laying i.e. assistance to pipe fitters by carrying and placing pipes and fittings in position, curing, assistance to masons, loading and unloading. Thus, such items are not separately analysed but considered as daily labourers and other direct project beneficiaries.
- There are cases where four daily labourers have been considered say to produce a unit volume of excavation in all types of soil and other items. These are supposed to be consistent with hourly working periods of other supporting equipment.
- Construction method is assumed to be by commissioning/contracting-out the required machineries and equipment for the intended work. Thus, depreciation cost of equipment is not incorporated in the analysis of this rate.
- The first action of any planning engineer on a labour-based project should be to determine the quantities and type of work to be carried out. The engineer should then divide this work into activities that can be carried out by individuals or groups of workers, and then, by applying work norms, determine the required labour force and the duration of the project. Choosing the correct **work norm** is thus the most critical part of such analysis. We should thus be quite conscious and appreciate nature of the project and project organization before applying the productivity norms from different reference materials. That is, we shall assume the workforce is well organised and supervised, understand the work which is supposed to do, and has the correct hand-tools in good condition. It is also assumed that the worker/s is/are healthy, properly paid, working normal hours and has good access to food and water.
- **Workmanship:** All workmanship must be of the good quality appropriate to each category of work the materials which are of the good quality of their respective kinds as specified or described in the specification. Concrete shall be placed in the permanent works together with the client representative as they need to approve the materials of which it is composed. Approved materials shall not thereafter be altered or replaced by other materials without the consent of the client. Water for mixing or curing of concrete or mortar must be as pure as possible i.e. it shall not be mixed with soil or other chemicals or impurities.

### *3.5.2 Units of measurements*

So as to establish unit rates of items, we need to know their measurement units. The units of measurements for civil engineering works are mainly categorized for their nature, shape and size and for making payments to the contractor. The principle of units of measurements normally consists the following:

- Single units work is expressed in numbers (Nr), like gate structures, pipe laying, doors, windows, trusses, etc.,
- Works done in one large amount on one occasion are expressed in lump sum (LS), like Mobilization, Demobilization, temporary works, etc.,
- Works consisting of linear measurements involve length are expressed in running metres (m) like hand rail, cornice, fencing, bands of specified width, etc.,
- Works consisting of mass measurements involve weight and are expressed in kilogram (kg) like reinforcement bars, deformed bars, barbed/mesh wire, Nails of different sizes (roof & others), etc.,
- Works consisting of areal surface measurements involve area and are expressed in square meters ($m^2$) like plastering, white washing, partitions of specified thickness, etc.,
- Works consisting of cubical contents which involve volume are expressed in Cubic metres ($m^3$) like earth work, cement concrete, Masonry, etc.

***Box 3-1:***

***Worked Example-2****: Consider the following raw data of construction materials and other related given data, which is prepared for the analysis of unit rate of Lower Silala (ANRS) SSI project. Based on these tables, estimate the expected unit rate for different activities like clearing, excavation, fill, backfill, masonry, plastering, C20 Concrete. Assume necessary data not given in these tables reasonably.*

**Table 3-2: Material procurement and transportation cost at lower-silala SSIP**

| S/N | DESCRIPTION | UNIT | Cost (ETB) | Remark |
|---|---|---|---|---|
| I | Material | | | |
| | Cement (Portland) | qt | 300.00 | Portland type |
| | Sand | $m^3$ | 500.00 | |
| | Grave/ 2-4 cm ø | | 560.00 | |
| | − on-force | $m^3$ | 250.00 | |
| | − purchased | $m^3$ | 300.00 | |
| | Reinforced bar | qt | 1,785.08 | Average of listed bars |
| | − 6 mm ø | kg | 6.00 | |
| | − 8 mm ø | kg | 25.28 | |
| | − 10 mm ø | kg | 21.57 | |
| | − 12 mm ø | kg | 19.20 | |
| | − 14 mm ø | kg | 17.20 | |
| | Stone | $m^3$ | 35.00 | |
| | − Dressed | $m^3$ | 150.00 | |
| | − Undressed | $m^3$ | 120.00 | |
| | Selected material | $m^3$ | 30.00 | |
| | Timber | $m^3$ | 2,100.00 | 0.02 x 0.3 x 4.0 |
| | Eucalyptus Rafter, 120 mm ø | No | 50.00 | |
| | Eucalyptus poles 70-80 mm | No | 20.00 | |
| | CIS 32 Gauge | No | 165.00 | |
| | Plywood | $m^2$ | 47.30 | |
| | Chipwood | $m^2$ | 177.00 | |
| | Morale (4x5) | $m^2$ | 5.00 | |
| | Roof Nail | kg | 25.00 | |
| | Soft Wire | $m^2$ | 45.00 | |
| | Gabion | $m^3$ | 350.00 | |
| | RC Pipe, 1000 mm ø | No | 450.00 | 1m length |

| S/N | DESCRIPTION | UNIT | Cost (ETB) | Remark |
|---|---|---|---|---|
| | nPVC pipe of DN400 | m | 564.60 | AAWSSA cost/m, 2007 |
| | DN350 | m | 455.60 | " |
| | DN315 | m | 346.63 | " |
| | DN280 | m | 287.01 | " |
| | DN225 | m | 186.98 | " |
| | DN160 | m | 96.37 | " |
| | DN140 | m | 64.34 | " |
| | DN110 | m | 46.42 | " |
| | DN90 | m | 49.50 | " |
| | DN75 | m | 40.50 | " |
| | DN63 | m | 38.40 | " |
| | DN50 | m | 24.00 | " |
| | DN32 | m | 7.30 | " |
| | Geo-membrane and Geo-net lining | m² | 17.77 | OWWDSE cost/m², 2008 |
| | Geo-net | m² | 8.04 | |
| | CIS Sheet, G32 | m² | 165.00 | |
| | CIS Sheet, G30 | m² | 260.00 | |
| | Painting | m² | 60.00 | |
| | Galvanized Iron pipe 1/2" | m | 24.17 | |
| | 3/4" | m | 33.33 | |
| | 1" | m | 75.00 | |
| | 1 1/2" | m | 108.33 | |
| | 2" | m | 145.00 | |
| | 2 1/2" | m | 182.17 | |
| | 3" | m | 193.33 | |
| | 4" | m | 258.33 | |
| | 6" | m | 286.67 | |
| | Water-stop | m | 20.00 | |

**Table 3-3: Loading-unloading cost for construction materials data**

| S/N | Material | Load-Unload cost | | | Remark |
|---|---|---|---|---|---|
| | | (ETB/kg) | (ETB/m³) | (ETB/pcs) | |
| 1 | Sand | | | | Not considered for the truck dumps itself |
| 2 | Gravel | | | | " |
| 3 | Stone | | | | " |
| 4 | Timber | | | | " |
| 5 | Cement | | | 5.00 | Sometimes load & unload is not considered as daily laborers themselves are assumed to do it |
| 6 | Reinforcement bar | | | 2.00 | |
| 7 | Selected material | | 5 | | " |
| 8 | Eucalyptus poles | | | 3.00 | " |
| 9 | Eucalyptus poles | | | 3.00 | " |
| 10 | CIS 32 Gauge | | | 2.00 | " |
| 11 | Plywood | | | 2.00 | " |
| 12 | Chipwood & Formwork | | | 3.00 | " |
| 13 | Morale (4x5) | | | 2.00 | " |
| 14 | Roof Nail | 2.00 | | | " |
| 15 | Soft Wire | | 2.00 | | " |

| S/N | Material | Load-Unload cost | | | Remark |
|---|---|---|---|---|---|
| | | (ETB/kg) | (ETB/m³) | (ETB/pcs) | |
| 16 | Gabion | | 2.00 | | ″ |
| 17 | RC Pipe, of different ø | | | 5.00 | ″ |
| 18 | PVC pipes of different ø | | 5.00 | | |

**Table 3-4: Transportation cost to lower-silala ssi project**

| S/N | Material | Distance of Proj. site to supply source (km) | Unit Rental Rate | | Total Trans. Cost | | Material cost at construction site | Remarks |
|---|---|---|---|---|---|---|---|---|
| | | | (ETB/ km/qt.) | ETB/km /m³) | (ETB/qt.) | (ETB/m³) | | |
| 1 | Sand | 90 | | 3.60 | | 324.00 | 824.00 | |
| 2 | Gravel | 50 | | 3.80 | | 190.00 | 750.00 | |
| 3 | Stone | 5 | | 4.80 | | 24.00 | 59.00 | Average cost |
| 4 | Timber | 60 | | 1.00 | | 60.00 | 86.40 | Cost is per $m^2$ |
| 5 | Cement | 350 | 0.10 | | 35.00 | | 335.00 | |
| 6 | Reinforcement bar | 350 | 0.10 | | 35.00 | | 1,820.08 | |
| 7 | Selected material | 5 | | 4.80 | | 24.00 | 54.00 | |
| 8 | Eucalyptus Rafter | 20 | | 1.61 | | 32.20 | 82.20 | |
| 9 | Eucalyptus poles | 20 | | | | 0.90 | 20.90 | |
| 10 | CIS 32 Gauge | 350 | | 0.003 | | 0.98 | 165.98 | Cost is per $m^2$ |
| 11 | Plywood | 350 | | 0.01 | | 2.45 | 49.75 | Cost is per $m^2$ |
| 12 | Chipwood | 350 | | 0.01 | | 2.45 | 179.45 | Cost is per $m^2$ |
| 13 | Morale (4x5) | 350 | | 0.003 | | 0.98 | 5.98 | Cost is per m length |
| 14 | Roof Nail | 350 | 0.20 | | 70.00 | | 95.00 | Per quintal |
| 15 | Soft Wire | 350 | 0.20 | | 70.00 | | 115.00 | Per quintal |
| 16 | Gabion | 350 | 0.20 | | 14.00 | | 364.00 | Assume $1m^3$=20kg |
| 17 | Geo-membrane lining | 90 | 0.20 | | 18.00 | | 35.77 | |
| 18 | Geo-net | 90 | 0.20 | | 18.00 | | 26.04 | |

**Table 3-5: Labor costs to be adopted for these civil works**

| S/N | Work Items | Wage & other expenses (ETB) | | Wage (ETB/hr) | Remark |
|---|---|---|---|---|---|
| | | Daily | Monthly | | |
| 1 | Daily Laborer | 80.00 | | 10.00 | Unskilled |
| 2 | Time/Store keeper | 100.00 | | 12.50 | Semi-skilled |
| 3 | Mason | 200.00 | | 25.00 | Semi-skilled |
| 4 | Plasterer | 200.00 | | 25.00 | " |
| 5 | Bar bender | 200.00 | | 25.00 | " |
| 6 | Carpenter | 200.00 | | 25.00 | " |
| 7 | Skilled Laborer | 200.00 | | 25.00 | " |
| 8 | Plumber | 200.00 | | 25.00 | " |
| 9 | Painter | 200.00 | | 25.00 | " |
| 10 | Welder | 200.00 | | 25.00 | " |
| 11 | General Forman | 250.00 | 4,000.00 | 47.92 | |
| 12 | Surveyor | 250.00 | 5,000.00 | 52.08 | |
| 13 | Senior surface water Officer/ Construction Engineer | 250.00 | 8,000.00 | 64.58 | Professional |
| 14 | Project Coordinator/manager | 250.00 | 12,000.00 | 81.25 | " |

Note: Machine operator costs are included in the equipment rental rates

**Table 3-6: Equipment rental rates to be adopted for this unit rate analysis**

| S/N | Type of Equipment | Specification | Sofamar (2008/9) | | OWWSDE (2008/9) | | OWWCE (2008/9) | | Average (2008/9) | Proposed for(2016) |
|---|---|---|---|---|---|---|---|---|---|---|
| | | | Capacity | Rental Rate (Birr/ Hr) | Capacity | Rental Rate (Birr/Hr) | Capacity | Rental Rate (Birr/Hr) | Rental Rate (Birr/Hr) | Rental Rate (Birr/Hr) |
| 1 | Bull Dozer | 140-200FWHP | D8 | 1293.00 | | 1326.00 | D8R | 1,375.00 | 1,331.33 | 5325.33 |
| 2 | Bull Dozer | 200-300FWHP | D7 | 1047.00 | | | D8N | 1,403.00 | 1,225.00 | 4900.00 |
| 3 | Bull Dozer W/ripper | 200-300FWHP | | | | | D9N | 1,370.00 | 1,370.00 | 5480.00 |
| 4 | Motor Grader | 140-200FWHP | 140H | 793.00 | | 810.00 | <140hp | 782.00 | 795.00 | 3180.00 |
| 5 | Grader | | | | | | >140hp | 802.00 | 802.00 | 3208.00 |
| 6 | Wheel Loader | 2 - 2.5 m³ | 195G (3.5) | 643.00 | | 457.00 | 2-3 m³ | 419.00 | 506.33 | 2025.33 |
| 7 | Loader | | | | | | >3m³ | 440.00 | 440.00 | 1760.00 |
| 8 | Excavator | | | | | | 1-1.5m³ | 690.00 | 690.00 | 2760.00 |
| 9 | Excavator | | | | | | 1.5-1.8 | 700.00 | 700.00 | 2800.00 |
| 10 | Traxcavator | 2 - 2.5 m³ | 330L (1.5) | 794.00 | | 890.00 | >1.8 | 987.00 | 890.33 | 3561.33 |
| 11 | Compactor Roller | 8 -10 ton | 12ton | 432.00 | | 15.00 | 10-14 ton | 396.00 | 281.00 | 1124.00 |
| 12 | Compactor Roller | | | | | | >=15 ton | 410.00 | 410.00 | 1640.00 |
| 13 | Dump Truck | 7m³ | 16m³ | 408.00 | | 10.50 | d/t rates/ dist. | | 209.25 | 837.00 |
| 14 | Dump Truck | 10m³ | 14m³ | 385.00 | | | | | 385.00 | 1540.00 |
| 15 | Dump Truck | 12m³ | 12m³ | 162.00 | | | | | 162.00 | 648.00 |
| 16 | Dump Truck | 14m³ | 10m³ | 293.00 | | | | | 293.00 | 1172.00 |
| 17 | Dump Truck | 16m³ | | | | | | | | |
| 18 | Water Truck | 12000-14000lit | 14000lit | 983.00 | | 150.00 | 13000 lit | 210.00 | 447.67 | 1790.67 |
| 19 | Water Tanker | 3000lit | 13000lit | 843.00 | | | | | 843.00 | 3372.00 |
| 20 | Tractor Scraper | 15-20 m³ | | | | | | | | |
| 21 | Crusher Plant | 75tph | | | | | 1-1.2 m³ | 380.00 | 380.00 | 1520.00 |
| 22 | Concrete Mixer | 250lit | | | | | 1.2-1.5 | 385.00 | 385.00 | 1540.00 |
| 23 | Concrete Mixer | 500lit | | | 5m³ | 265.00 | 1.5-2m³ | 403.00 | 334.00 | 1336.00 |
| 24 | Concrete Mixer | 1000lit | | | | | 2-2.5m³ | 408.00 | 408.00 | 1632.00 |

| S/N | Type of Equipment | Specification | Sofamar (2008/9) | | OWWSDE (2008/9) | | OWWCE (2008/9) | | Average (2008/9) | Proposed for(2016) |
|---|---|---|---|---|---|---|---|---|---|---|
| | | | Capacity | Rental Rate (Birr/ Hr) | Capacity | Rental Rate (Birr/Hr) | Capacity | Rental Rate (Birr/Hr) | Rental Rate (Birr/Hr) | Rental Rate (Birr/Hr) |
| 25 | Transit Mixer | 1000m³ | 1.6m³ | 330.00 | | | 2.5-3m³ | 431.00 | 380.50 | 1522.00 |
| 26 | Transit Mixer | | | | | | 3-5m³ | 460.00 | 460.00 | 1840.00 |
| 27 | Transit Mixer | | | | | | 5 to6m³ | 489.00 | 489.00 | 1956.00 |
| 28 | Transit Mixer | | | | | | 6-7 m³ | 517.00 | 517.00 | 2068.00 |
| 29 | Transit Mixer | | | | | | >7m³ | 546.00 | 546.00 | 2184.00 |
| 30 | Concrete Vibrator | 4hp | | | | 5.50 | | | 5.50 | 22.00 |
| 31 | Compressor | 7m³/min | | | | | | | | |
| 32 | Wagon Drill Crawler | 4500kg | | | | | | | | |
| 33 | Jack Hammer | 25kg | | | | 295.00 | | | 295.00 | 1180.00 |
| 34 | Water Pump | 230lit | | | | | | | | |
| 35 | Hand Tamper | - | | | | | | | | |
| 36 | Steel Cutter | - | | | | 1.50 | | | 1.50 | 6.00 |
| 37 | Pipe Mould | - | | | | | | | | |
| 38 | Hand Tools | - | | | | 5.26 | | | 5.26 | 21.04 |
| 39 | Service Car | | | | | | | | 100.00 | 400.00 |
| 40 | Welding Machine | | | | | | | 70.00 | 70.00 | 280.00 |

***Solution**: This analysis requires estimating materials required for each activity and their current cost as well as utilization factors for human resources and equipment on the project site. For example, utilization factor of 0.25 for site engineer means he/she will stay with that specific activity the whole working day and the remaining 0.75 will be distributed according to the weight of the activity (of-course that should be within the project site or related work). The same is true for the case of machineries or equipment utilization.*

**Table 3-7: Details of Worked out Unit Rates Breakdown and Analysis**

**Work item-1 : Site clearance and removal of top soil to a max. depth of 20 cm /m²**

Total Quantity of Work Item 1m²

Hourly output **1000.0** $M^2$/hr

Equipment Output (Dozer)

If Manual **12.5** $M^2$/hr

Profit & Over Head Cost - 25%

| MATERIAL COST (a) | | | | | LABOUR COST (b) | | | | | EQUIPMENT COST (c) | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Type of Material** | **Unit** | **Qty** | **U.Price*** | **T.Cost** | **Trade** | **No** | **UF** | **Wage** | **Hourly** | **Equipment** | **No** | **UF** | **Rental** | **Hourly** |
| Pickaxe | Pcs | 4 | 40 | 0.33 | DL | 4 | 1 | 10.00 | 40.00 | Dozer | 1 | 100% | 4900.00 | 4900.00 |
| Spade | Pcs | 4 | 40 | 0.33 | Surveyor | 1 | 0.25 | 52.08 | 13.02 | Service vehic. | 1 | 15% | 400.00 | 60.00 |
| Wheel Barrow | Pcs | 4 | 40 | 0.33 | Forman | 1 | 0.25 | 47.92 | 11.98 | Dump truck | 1 | 100% | 1540.00 | 1540.00 |
| | | | | | Con. Engin. | 1 | 0.15 | 64.58 | 9.69 | Loader | 1 | 100% | 2025.33 | 2025.33 |
| | | | | | Site Manager | 1 | 0.05 | 81.25 | 4.06 | | | | | 0.00 |
| **Sub Total (1a)** | | | | **1.00** | **Sub Total (1b)** | | | | **78.75** | **Sub Total (1c)** | | | | **8525.33** |

| | | | |
|---|---|---|---|
| Direct Cost per hr = | 8.61 | If manual | 139.75 |
| Profit & Over Head = | 2.15 | | 34.94 |
| Total Cost per m² of clearing | **10.76** | | **13.98** ETB/$m^2$ |

**Work item-2 : Excavation in common soil except rock and disposal for haul distance within 500m**

Total Quantity Of Work Item 1m³

Hourly Output ( Excavator) **50** $M^3$/hr

If Manual **1.0** $M^3$/hr

| MATERIAL COST (a) | | | | | LABOUR COST (b) | | | | | EQUIPMENT COST (c) | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Type of Material** | **Unit** | **Qty** | **U.Price*** | **T.Cost** | **Trade** | **No** | **UF/MD** | **Wage** | **Hourly** | **Equipment** | **No** | **UF** | **Rental** | **Hourly** |
| Pickaxe | Pcs | 4 | 40 | 0.33 | DL | 4 | 1 | 10.00 | 40.00 | Excavator | 1 | 100% | 2,800.00 | 2800.00 |
| Spade | Pcs | 4 | 40 | 0.33 | Surveyor | 1 | 0.25 | 52.08 | 13.02 | Service vehic. | 1 | 15% | 400.00 | 60.00 |
| Wheel Barrow | Pcs | 4 | 40 | 0.33 | Forman | 1 | 0.25 | 47.92 | 11.98 | Dump truck | 1 | 100% | 1540.00 | 1540.00 |
| | | | | | Con. Engin. | 1 | 0.15 | 64.58 | 9.69 | | | | | 0.00 |
| | | | | | Site Manager | 1 | 0.05 | 81.25 | 4.06 | | | | | 0.00 |
| **Sub Total (2a)** | | | | **1.00** | **Sub Total (2b)** | | | | **78.75** | **Sub Total (2c)** | | | | **4400.00** |

| | | | |
|---|---|---|---|
| Direct Cost per hr = | 4,479.75 | If manual | 80.69 |
| Profit & Over Head = | 1,119.94 | | 20.17 |
| Total Cost per m³ of exca. | **111.99** | | **100.86** ETB/$m^3$ |

Hourly Output **35.00** $M^3$/hr

**Work Item-3** : **Fill with selected material from excavation, including compaction /on-spot/**

Equipment Output (Loader)

Total Quantity of Work Item 1m³

If Manual **2.50** $M^3$/hr

| MATERIAL COST (a) | | | | | LABOUR COST (b) | | | | | EQUIPMENT COST (c) | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Type of Material** | **Unit** | **Qty** | **U.Price*** | **T.Cost** | **Trade** | **No** | **UF** | **Wage** | **Hourly** | **Equipment** | **No** | **UF** | **Rental** | **Hourly** |
| Pickaxe | Pcs | 10 | 40 | 0.83 | DL | 10 | 1 | 10.00 | 100.00 | Loader | 1 | 100% | 2025.33 | 2025.33 |
| Spade | Pcs | 10 | 40 | 0.83 | Surveyor | 1 | 0.25 | 52.08 | 13.02 | Service vehic. | 1 | 15% | 400.00 | 60.00 |
| Wheel Barrow | Pcs | 10 | 40 | 0.83 | Forman | 1 | 0.25 | 47.92 | 11.98 | Dump Truck | 1 | 100% | 1540.00 | 1540.00 |
| | | | | 0.00 | Con. Engin. | 1 | 0.15 | 64.58 | 9.69 | | | | | 0.00 |
| | | | | 0.00 | Site Manager | 1 | 0.05 | 81.25 | 4.06 | | | | | 0.00 |
| **Sub Total (3a)** | | | | **2.50** | **Sub Total (3b)** | | | | **138.75** | **Sub Total (3c)** | | | | **3625.33** |

| | | | |
|---|---|---|---|
| Direct Cost per hr = | 3,766.58 | If manual | 82.00 |
| Profit & Over Head = | 941.65 | | 20.50 |
| Total Cost per m³ of backfill | **134.52** | | **102.50** ETB/$m^3$ |

Hourly Output **112.50** $M^3$/hr

Equipment Output (Loader)

**Work Item-4** : **Fill with selected material from borrow pits with in haul distance 20km, including compaction**

If Manual **1.88** $M^3$/hr

Total Quantity of Work Item 1m³

| MATERIAL COST (a) | | | | | LABOUR COST (b) | | | | | EQUIPMENT COST (c) | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Type of Material** | **Unit** | **Qty** | **U.Price*** | **T.Cost** | **Trade** | **No** | **UF** | **Wage** | **Hourly** | **Equipment** | **No** | **UF** | **Rental** | **Hourly** |
| Pickaxe | Pcs | 10 | 40 | 0.83 | DL | 10 | 1 | 10.00 | 100.0 | Loader | 1 | 100% | 2025.33 | 2025.33 |
| Spade | Pcs | 10 | 40 | 0.83 | Surveyor | 1 | 0.25 | 52.08 | 13.02 | Service vehic. | 1 | 15% | 400.00 | 60.00 |
| Wheel Barrow | Pcs | 10 | 40 | 0.83 | Forman | 1 | 0.25 | 47.92 | 11.98 | Compactor | 2 | 100% | 1,124.00 | 2248.00 |
| | | | | 0.00 | Con. Engin. | 1 | 0.15 | 64.58 | 9.69 | Dozer | 1 | 100% | 4900.00 | 4900.00 |
| | | | | 0.00 | Site Manager | 1 | 0.05 | 81.25 | 4.06 | Dump Truck | 2 | 100% | 1540.00 | 3080.00 |
| | | | | 0.00 | | | | | 0.00 | Shower Truck | 1 | 50% | 1,790.67 | 895.33 |
| | | | | 0.00 | | | | | 0.00 | Grader | 1 | 100% | 3180.00 | 3180.00 |
| Sub Total (4a) | | | | 2.50 | Sub Total (4b) | | | | 138.75 | Sub Total (4c) | | | | 16388.67 |

| | | | |
|---|---|---|---|
| Direct Cost per hr = | 146.93 | If manual | 201.25 |
| Profit & Over Head = | 36.73 | | 50.31 |
| Total Cost per m³ of compaction. | **183.67** | | **134.17** ETB/$m^3$ |

Hourly Output **200.00**

**Work Item-5** **Extra over for above earth works items/Cart away for haulage distance beyond 500m**

Equipment Output (Mixer)

Total Quantity Of Work Item 1m³

If Manual **7.50** M³/hr

| MATERIAL COST (a) | | | | | LABOUR COST (b) | | | | | EQUIPMENT COST (c) | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Type of Material** | **Unit** | **Qty** | **U.Price*** | **T.Cost** | **Trade** | **No** | **UF** | **Wage** | **Hourly** | **Equipment** | **No** | **UF** | **Rental** | **Hourly** |
| Spade | Pcs | 2 | 40 | 0.17 | Forman | 1 | 1 | 47.92 | 47.92 | Dozer | 1 | 100% | 4900.00 | 4900.00 |
| Wheel Barrow | Pcs | 2 | 40 | 0.17 | Laborer | 2 | 1 | 10.00 | 20.00 | Service vehic. | 1 | 15% | 400.00 | 60.00 |
| | | | | 0.00 | Con. Eng. | 1 | 0.15 | 64.58 | 9.69 | Dump Truck | 1 | 100% | 4.80 | 4.80 |
| | | | | 0.00 | Site Manager | 1 | 0.05 | 81.25 | 4.06 | Loader | 1 | 100% | 2,025.33 | 2025.33 |
| **Sub Total (5a)** | | | | **0.33** | **Sub Total (5b)** | | | | **81.67** | **Sub Total (5c)** | | | | **6990.13** |

| | | | |
|---|---|---|---|
| Direct Cost per hr = | 35.69 | If Manual | 142.00 |
| Profit & Over Head = | 8.92 | | 35.50 |
| Total Cost per m³ of disposal. | **44.62** | | **23.67** ETB/m³ |

Hourly Output **9.20**

**Work Item-6** **Excavation in rock and disposal for haul distance with in 500m**

Equipment Output (Excavator)

Total Quantity Of Work Item 1m³

If Manual **0.23** M³/hr

| MATERIAL COST (a) | | | | | LABOUR COST (b) | | | | | EQUIPMENT COST (c) | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Type of Material** | **Unit** | **Qty** | **U.Price*** | **T.Cost** | **Trade** | **No** | **UF** | **Wage** | **Hourly** | **Equipment** | **No** | **UF** | **Rental** | **Hourly** |
| Pickaxe | Pcs | 2 | 40 | 0.17 | DL | 2 | 1 | 10.00 | 20.00 | Service vehic. | 1 | 15% | 400.00 | 60.00 |
| Spade | Pcs | 2 | 40 | 0.17 | Surveyor | 1 | 0.25 | 52.08 | 13.02 | Jack Hummer | 1 | 100% | 4570.00 | 4570.00 |
| Wheel Barrow | Pcs | 2 | 40 | 0.17 | Forman | 1 | 0.25 | 47.92 | 11.98 | | | | | 0.00 |
| Chisel | Pcs | 2 | 200 | 0.83 | Con. Engin. | 1 | 0.15 | 64.58 | 9.69 | | | | | 0.00 |
| | | | | | Site Manager | 1 | 0.05 | 81.25 | 4.06 | | | | | 0.00 |
| **Sub Total (6a)** | | | | **1.33** | **Sub Total (6b)** | | | | **58.75** | **Sub Total (6c)** | | | | **4630.00** |

| | | | |
|---|---|---|---|
| Direct Cost per hr = | 510.98 | If Manual | 90.71 |
| Profit & Over Head = | 127.75 | | 22.68 |
| Total Cost per m³ of Excavation. | **638.73** | | **503.94** ETB/m³ |

Hourly Output **2.00**

**Work Item-7** **Stone masonry work above OGL with mortar mix 1:3** Equipment Output (1.0 m³ Mixer)

Total Quantity Of Work Item 1m³ If Manual **1.00** $M^3$/hr

| MATERIAL COST (a) | | | | | LABOUR COST (b) | | | | | EQUIPMENT COST (c) | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Type of Material** | **Unit** | **Qty** | **U.Price*** | **T.Cost** | **Trade** | **No** | **UF** | **Wage** | **Hourly** | **Equipment** | **No** | **UF** | **Rental** | **Hourly** |
| Stone | $M^3$ | 1.25 | 59.00 | 73.75 | Forman | 1 | 0.5 | 47.92 | 23.96 | Simple Tool | 1 | 100% | 6.75 | 6.75 |
| Sand | $M^3$ | 0.3 | 824.00 | 247.20 | Mason | 4 | 1 | 25.00 | 100.00 | Service vehic. | 1 | 15% | 400.00 | 60.00 |
| Cement | qts | 0.8 | 335.00 | 268.00 | Laborer | 8 | 1 | 10.00 | 80.00 | Shower Truck | 1 | 100% | 1,790.67 | 1790.67 |
| Water | | | | 0.00 | Con. Eng. | 1 | 0.15 | 64.58 | 9.69 | Mixer | 1 | 100% | 1,522.00 | 1522.00 |
| | | | | | Site Manager | 1 | 0.05 | 81.25 | 4.06 | | | | | 0.00 |
| **Sub Total (7a)** | | | | **588.95** | **Sub Total (7b)** | | | | **217.71** | **Sub Total (7c)** | | | | **3379.42** |

Direct Cost per hr = 2,387.51 If Manual 2,500.79

Profit & Over Head = 596.88 625.20

Total Cost per m³ of Masonry **2,984.39** **3,125.99** ETB/$m^3$

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Hourly Output **2.00**

**Work Item-8** **Stone masonry work below OGL with mortar mix 1:3** Equipment Output (1.8m³ Mixer)

Total Quantity Of Work Item 1m³ If Manual **1.00** $M^3$/hr

| MATERIAL COST (a) | | | | | LABOUR COST (b) | | | | | EQUIPMENT COST (c) | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Type of Material** | **Unit** | **Qty** | **U.Price*** | **T.Cost** | **Trade** | **No** | **UF** | **Wage** | **Hourly** | **Equipment** | **No** | **UF** | **Rental** | **Hourly** |
| Stone | M3 | 1.3 | 59.00 | 76.70 | Forman | 1 | 0.5 | 47.92 | 23.96 | Simple Tools | 1 | 100% | 6.75 | 6.75 |
| Sand | M3 | 0.3 | 824.00 | 247.20 | Mason | 4 | 1 | 25.00 | 100.00 | Service vehic. | 1 | 15% | 400.00 | 60.00 |
| Cement | qts | 0.8 | 335.00 | 268.00 | Laborer | 8 | 1 | 10.00 | 80.00 | Shower Truck | 1 | 100% | 1,790.67 | 1790.67 |
| | | | | | Con. Eng. | 1 | 0.15 | 64.58 | 9.69 | Mixer | 1 | 100% | 1,522.00 | 1522.00 |
| | | | | | Site Manager | 1 | 0.05 | 81.25 | 4.06 | | | | | 0.00 |
| Sub Total (8a) | | | | 591.90 | Sub Total (8b) | | | | 217.71 | Sub Total (8c) | | | | 3379.42 |

Direct Cost per hr = 2,390.46 If manual 2,503.74

Profit & Over Head = 597.62 625.94

Total Cost per m³ of Masonry **2,988.08** **3,129.68** ETB/$m^3$

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Hourly Output **5.00**

**Work Item-9** **Supply, cut, bend and fix in position high yield steel reinforcement bars of different dia.** Equipment Output (Bar Cutter)

Total Quantity Of Work Item 1kg

| MATERIAL COST (a) | | | | | LABOUR COST (b) | | | | | EQUIPMENT COST (c) | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Type of Material** | **Unit** | **Qty** | **U.Price*** | **T.Cost** | **Trade** | **No** | **UF** | **Wage** | **Hourly** | **Equipment** | **No** | **UF** | **Rental** | **Hourly** |
| Reinforcement bar | | | | 0.00 | Bar bender | 1 | 1 | 25.00 | 25.00 | bar cutter | 1 | 100% | 1.25 | 1.25 |
| Diff. Diameter | kg | 1.1 | 18.20 | 20.02 | Forman | 1 | 1 | 47.92 | 47.92 | Service vehic. | 1 | 15% | 400.00 | 60.00 |
| soft wire | kg | 0.05 | 1.15 | 0.06 | Daily Laborer | 4 | 1 | 10.00 | 40.00 | | | | | 0.00 |
| | | | | 0.00 | | | | | | | | | | 0.00 |
| Sub Total (9a) | | | | 20.08 | Sub Total (9b) | | | | 112.92 | Sub Total (9c) | | | | 61.25 |

| | |
|---|---|
| Direct Cost per hr = | 54.91 |
| Profit & Over Head = | 13.73 |
| Total Cost per kg of Re-bar | **68.64** |

**Work Item-10** **Form work (cutting and fixing)** Hourly Output **10.00**

Total Quantity Of Work Item 1m² (Person Power) m²/d

| MATERIAL COST (a) | | | | | LABOUR COST (b) | | | | | EQUIPMENT COST (c) | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Type of Material** | **Unit** | **Qty** | **U.Price*** | **T.Cost** | **Trade** | **No** | **UF** | **Wage** | **Hourly** | **Equipment** | **No** | **UF** | **Rental** | **Hourly** |
| 3 mm thick Timber | m2 | 1.1 | 86.40 | 95.04 | Forman | 1 | 0.25 | 47.92 | 11.98 | Simple Tools | 1 | 100% | 6.75 | 6.75 |
| Nails | kg | 0.15 | 15 | 2.25 | Carpenter | 1 | 1 | 25.00 | 25.00 | Service vehic. | 1 | 15% | 400.00 | 60.00 |
| Euc. poles | m3 | 1 | 20.90 | 20.90 | Con. Eng. | 1 | 0.15 | 64.58 | 9.69 | | | | | 0.00 |
| | | | | | D/L | 4 | 1 | 10.00 | 40.00 | | | | | 0.00 |
| Sub Total (10a) | | | | 118.19 | Sub Total (10b) | | | | 86.67 | Sub Total (10c) | | | | 66.75 |

| | | |
|---|---|---|
| Direct Cost per hr = | 133.53 | |
| Profit & Over Head = | 33.38 | |
| Total Cost per $m^2$ of form | **166.91** | ETB/$m^2$ |

**Work Item -11 Plastering Works**

Hourly Output **30.00** $m^2$/d

Total Quantity Of Work Item 1 m2

(Person Power)

| MATERIAL COST (a) | | | | | LABOUR COST (b) | | | | | EQUIPMENT COST (c) | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Type of Material** | **Unit** | **Qty** | **U.Price*** | **T.Cost** | **Trade** | **No** | **UF** | **Wage** | **Hourly** | **Equipment** | **No** | **UF** | **Rental** | **Hourly** |
| Cement | qts | 0.09 | 335.00 | 30.15 | Forman | 1 | 0.5 | 47.92 | 23.96 | Simple Tools | 1 | 100% | 6.75 | 6.75 |
| Sand | m3 | 0.021 | 824.00 | 17.30 | Plasterer | 1 | 1 | 25.00 | 25.00 | Shower Truck | 1 | 100% | 1,790.67 | 1790.67 |
| | | | | | D/L | 3 | 1 | 10.00 | 30.00 | Service vehic. | 1 | 15% | 400.00 | 60.00 |
| | | | | | Con. Eng. | 1 | 0.15 | 64.58 | 9.69 | | | | | 0.00 |
| | | | | | Site Manager | 1 | 0.05 | 81.25 | 4.06 | | | | | 0.00 |
| Sub Total (11a) | | | | 47.45 | Sub Total (11b) | | | | 92.71 | Sub Total (11c) | | | | 1857.42 |

| | |
|---|---|
| Direct Cost per hr = | 112.46 |
| Profit & Over Head = | 28.11 |
| Total Cost per m2 of plastering | **140.57** |

**Work Item -12 Pointing work**

Hourly Output **30.00** $m^2$/d

Total Quantity Of Work Item 1 m2

(Person Power)

| MATERIAL COST (a) | | | | | LABOUR COST (b) | | | | | EQUIPMENT COST (c) | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Type of Material** | **Unit** | **Qty** | **U.Price*** | **T.Cost** | **Trade** | **No** | **UF** | **Wage** | **Hourly** | **Equipment** | **No** | **UF** | **Rental** | **Hourly** |
| Cement | qts | 0.028 | 335.00 | 9.38 | Forman | 1 | 0.5 | 47.92 | 23.96 | Simple Tools | 1 | 100% | 6.75 | 6.75 |
| Sand | m3 | 0.03 | 824.00 | 24.72 | Mason | 1 | 1 | 25.00 | 25.00 | Shower Truck | 1 | 100% | 1,790.67 | 1790.67 |
| | | | | 0.00 | Chiseler | 1 | 1 | 10.00 | 10.00 | Service vehic. | 1 | 15% | 400.00 | 60.00 |
| | | | | 0.00 | D/L | 4 | 1 | 10.00 | 40.00 | | | | | 0.00 |
| | | | | 0.00 | Con. Eng. | 1 | 0.15 | 25.00 | 3.75 | | | | | 0.00 |
| Sub Total (12a) | | | | 34.10 | Sub Total (12b) | | | | 102.71 | Sub Total (12c) | | | | 1857.42 |

| | |
|---|---|
| Direct Cost per hr = | 99.44 |
| Profit & Over Head = | 24.86 |
| Total Cost per m2 of pointing | **124.30** |

Hourly Output **10.00** $M^2/d$
Person Power

**Work Item -13 40cm thick basaltic or equivalent stone hard core well rolled, consolidated & blinded with crushed stone**
Total Quantity Of Work Item 1m2

| MATERIAL COST (a) | | | | | LABOUR COST (b) | | | | | EQUIPMENT COST (c) | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Type of Material** | **Unit** | **Qty** | **U.Price*** | **T.Cost** | **Trade** | **No** | **UF** | **Wage** | **Hourly** | **Equipment** | **No** | **UF** | **Rental** | **Hourly** |
| Stone | $m^3$ | 2 | 59.00 | 118.00 | Forman | 1 | 0.15 | 47.92 | 7.19 | Service vehic. | 1 | 15% | 400.00 | 60.00 |
| Chisel | Pcs | 2 | 200.00 | 0.83 | Mason | 1 | 1 | 25.00 | 25.00 | Dump Truck | 1 | 15% | 4.80 | 0.72 |
| | | | | 0.00 | Laborer | 2 | 1 | 10.00 | 20.00 | | | | | 0.00 |
| | | | | 0.00 | Surveyor | 1 | 0.15 | 52.08 | 7.81 | | | | | 0.00 |
| | | | | 0.00 | Con. Eng. | 1 | 0.15 | 64.58 | 9.69 | | | | | 0.00 |
| Sub Total (13a) | | | | 118.83 | Sub Total (13b) | | | | 69.69 | Sub Total (13c) | | | | 60.72 |

Direct Cost per hr = 131.87
Profit & Over Head = 32.97
Total Cost per m2 of hard coring **164.84**

Hourly Output **2.00**
Equipment Output (Person Power)

**Work Item -14 Providing and placing Gabion and filling with stone**
Total Quantity of Work Item 1m3

| MATERIAL COST (a) | | | | | LABOUR COST (b) | | | | | EQUIPMENT COST (c) | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Type of Material** | **Unit** | **Qty** | **U.Price*** | **T.Cost** | **Trade** | **No** | **UF** | **Wage** | **Hourly** | **Equipment** | **No** | **UF** | **Rental** | **Hourly** |
| Stone | $m^3$ | 2 | 59.00 | 118.00 | Forman | 1 | 1 | 47.92 | 47.92 | Service vehic. | 1 | 15% | 400.00 | 60.00 |
| Gabion | $m^4$ | 1 | 364.00 | 364.00 | Mason | 1 | 1 | 25.00 | 25.00 | | | | | 0.00 |
| | | | | 0.00 | Laborer | 1 | 1 | 10.00 | 10.00 | | | | | 0.00 |
| | | | | 0.00 | Surveyor | 1 | 0.2 | 52.08 | 10.42 | | | | | 0.00 |
| | | | | 0.00 | Con. Eng. | 1 | 0.15 | 64.58 | 9.69 | | | | | 0.00 |
| Sub Total (14a) | | | | 482.00 | Sub Total (14b) | | | | 103.02 | Sub Total (14c) | | | | 60.00 |

Direct Cost per hr = 563.51
Profit & Over Head = 140.88
Total Cost per $m^3$ of Gabion **704.39**

**Work Item-15** **Stone Rip Rap/Dry Stone Pitching**

Hourly Output **10.00** $m^2/d$

Total Quantity Of Work Item 1m2

Equipment Output (Person Power)

| MATERIAL COST (a) | | | | | LABOUR COST (b) | | | | | EQUIPMENT COST (c) | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Type of Material** | **Unit** | **Qty** | **U.Price*** | **T.Cost** | **Trade** | **No** | **UF** | **Wage** | **Hourly** | **Equipment** | **No** | **UF** | **Rental** | **Hourly** |
| **Stone** | $m^3$ | 2 | 59.00 | 118.00 | Forman | 1 | 0.25 | 47.92 | 11.98 | Service vehic. | 1 | 15% | 400.00 | 60.00 |
| | | | | 0.00 | Mason | 1 | 1 | 25.00 | 25.00 | | | | | 0.00 |
| | | | | 0.00 | Laborer | 2 | 1 | 10.00 | 20.00 | | | | | 0.00 |
| | | | | 0.00 | Surveyor | 1 | 0.1 | 52.08 | 5.21 | | | | | 0.00 |
| | | | | 0.00 | Con. Eng. | 1 | 0.15 | 64.58 | 9.69 | | | | | 0.00 |
| Sub Total (15a) | | | | 118.00 | Sub Total (15b) | | | | 71.88 | Sub Total (15c) | | | | 60.00 |

| | |
|---|---|
| Direct Cost per hr = | 131.19 |
| Profit & Over Head = | 32.80 |
| Total Cost per m³ of Riprapg | **163.98** |

**Work Item -16** **20cm stripping & then 60 cm thick Red ash Surfacing**

Hourly Output **19.00** $m^3/d$

Total Quantity Of Work Item 1m²

Equipment Output (Person Power)

| MATERIAL COST (a) | | | | | LABOUR COST (b) | | | | | EQUIPMENT COST (c) | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Type of Material** | **Unit** | **Qty** | **U.Price*** | **T.Cost** | **Trade** | **No** | **UF** | **Wage** | **Hourly** | **Equipment** | **No** | **UF** | **Rental** | **Hourly** |
| Red Ash | $m^3$ | 0.313 | 824.00 | 257.50 | Forman | 1 | 1 | 47.92 | 47.92 | Loader | 1 | 4% | 2,025.33 | 79.80 |
| | | | | 0.00 | Mason | 1 | 1 | 25.00 | 25.00 | Service vehic. | 1 | 15% | 400.00 | 60.00 |
| | | | | 0.00 | Laborer | 4 | 1 | 10.00 | 40.00 | Dozer | 1 | 2% | 4900.00 | 117.72 |
| | | | | 0.00 | Surveyor | 1 | 0.2 | 52.08 | 10.42 | Truck | 1 | 1 | 14.7 | 14.70 |
| | | | | 0.00 | Con. Eng. | 1 | 0.15 | 64.58 | 9.69 | Shower Truck | 1 | 1 | 1,790.67 | 1790.67 |
| | | | | 0.00 | | | | | 0.00 | | | | | |
| Sub Total (16a) | | | | 257.50 | Sub Total (16b) | | | | 133.02 | Sub Total (16c) | | | | 2062.88 |

| | |
|---|---|
| Direct Cost per hr = | 2,453.41 |
| Profit & Over Head = | 613.35 |
| Total Cost per m³ of surfacing | **161.41** |

**Work Item -17** **Cyclopean concrete (Plum concrete i.e Mass concrete with 30% Rock)**

Total Quantity Of Work Item 1m³

Hourly Output **5.00** M³/hr
Equipment Output (1.8m³ Mixer)
If Manual **0.75** M³/hr

| MATERIAL COST (a) | | | | | LABOUR COST (b) | | | | | EQUIPMENT COST (c) | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Type of Material** | **Unit** | **Qty** | **U.Price*** | **T.Cost** | **Trade** | **No** | **UF** | **Wage** | **Hourly** | **Equipment** | **No** | **UF** | **Rental** | **Hourly** |
| Cement | qts | 1.92 | 335.00 | 643.20 | Forman | 1 | 0.25 | 47.92 | 11.98 | Simple Tools | 1 | 100% | 10 | 10.00 |
| Sand | m3 | 0.282 | 824.00 | 232.37 | Mason | 2 | 1 | 25.00 | 50.00 | Mixer | 1 | 100% | 1,522.00 | 1522.00 |
| Aggregate | m3 | 0.42 | 750.00 | 315.00 | Carpenter | 1 | 1 | 25.00 | 25.00 | Loader | 1 | 100% | 2,025.33 | 2025.33 |
| Stone | m3 | 0.75 | 59.00 | 44.25 | Bar Bender | 1 | 1 | 25.00 | 25.00 | Shower Truck | 1 | 10% | 1,790.67 | 179.07 |
| | | | | | D/L | 22 | 1 | 10.00 | 220.00 | Service vehic. | 1 | 15% | 400.00 | 60.00 |
| | | | | | Con. Eng. | 1 | 0.15 | 64.58 | 9.69 | | | | | 0.00 |
| | | | | | Site Manager | 1 | 0.05 | 81.25 | 4.06 | | | | | 0.00 |
| Sub Total (17a) | | | | 1234.82 | Sub Total (17b) | | | | 345.73 | Sub Total (17c) | | | | 3796.40 |

| | | | |
|---|---|---|---|
| Direct Cost per hr = | 2,063.24 | If Manual | 1,566.75 |
| Profit & Over Head = | 515.81 | | 391.69 |
| Total Cost per m³ of cyc. concrete | **2,579.05** | | **2,611.25** |

**Work Item -18** **C-10 Mass/Lean concrete (1:4:8)**

Total Quantity Of Work Item 1m³

Hourly Output **5.00** M³/hr
Equipment Output (1.8m³ Mixer)
If Manual **0.75** M³/hr

| MATERIAL COST (a) | | | | | LABOUR COST (b) | | | | | EQUIPMENT COST (c) | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Type of Material** | **Unit** | **Qty** | **U.Price*** | **T.Cost** | **Trade** | **No** | **UF** | **Wage** | **Hourly** | **Equipment** | **No** | **UF** | **Rental** | **Hourly** |
| Cement | qts | 1.5 | 335.00 | 502.50 | Forman | 1 | 0.25 | 47.92 | 11.98 | Simple Tools | 1 | 100% | 10.00 | 10.00 |
| Sand | m3 | 0.41 | 824.00 | 337.84 | Mason | 3 | 1 | 25.00 | 75.00 | Mixer | 1 | 50% | 1,522.00 | 761.00 |
| Aggregate | m3 | 0.82 | 750.00 | 615.00 | Carpenter | 1 | 1 | 25.00 | 25.00 | Vibrator | 1 | 100% | 22.00 | 22.00 |
| | | | | | Bar Bender | 1 | 1 | 25.00 | 25.00 | Loader | 1 | 100% | 2,025.33 | 2025.33 |
| | | | | | D/L | 22 | 1 | 10.00 | 220.00 | Shower Truck | 1 | 50% | 1,790.67 | 895.33 |
| | | | | | Con. Eng. | 1 | 0.15 | 64.58 | 9.69 | Service vehic. | 1 | 15% | 400.00 | 60.00 |
| | | | | | Site Manager | 1 | 0.05 | 81.25 | 4.06 | | | | | 0.00 |
| Sub Total (18a) | | | | 1455.34 | Sub Total (18b) | | | | 370.73 | Sub Total (18c) | | | | 3773.67 |

| | | | |
|---|---|---|---|
| Direct Cost per hr = | 2,284.22 | If Manual | 2,484.25 |
| Profit & Over Head = | 571.05 | | 621.06 |
| Total Cost per m³ of concrete | **2,855.27** | | **4,140.42** |

Hourly Output **5.00** $M^3$/hr

**Work Item -19 C-15 Reinforced concrete (1:3:6)**

Equipment Output (1.8m³ Mixer)

Total Quantity Of Work Item 1m³

If Manual **0.75** $M^3$/hr

| MATERIAL COST (a) | | | | | LABOUR COST (b) | | | | | EQUIPMENT COST (c) | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Type of Material** | **Unit** | **Qty** | **U.Price*** | **T.Cost** | **Trade** | **No** | **UF** | **Wage** | **Hourly** | **Equipment** | **No** | **UF** | **Rental** | **Hourly** |
| Cement | qts | 2.8 | 335.00 | 938.00 | Forman | 1 | 1 | 47.92 | 47.92 | Simple Tools | 1 | 100% | 10 | 10.00 |
| Sand | m3 | 0.47 | 824.00 | 387.28 | Mason | 3 | 1 | 25.00 | 75.00 | Mixer | 2 | 100% | 1,522.00 | 3044.00 |
| Aggregate | m3 | 0.7 | 750.00 | 525.00 | Carpenter | 1 | 1 | 25.00 | 25.00 | Vibrator | 1 | 100% | 22.00 | 22.00 |
| Water | | | | 0.00 | Bar Bender | 1 | 1 | 25.00 | 25.00 | Loader | 1 | 100% | 2,025.33 | 2025.33 |
| | | | | | D/L | 22 | 1 | 10.00 | 220.00 | Shower Truck | 1 | 20% | 1,790.67 | 358.13 |
| | | | | | Con. Eng. | 1 | 0.15 | 64.58 | 9.69 | Service vehic. | 1 | 15% | 400.00 | 60.00 |
| | | | | | Site Manager | 1 | 0.05 | 81.25 | 4.06 | | | | | |
| Sub Total (19a) | | | | 1850.28 | Sub Total (19b) | | | | 406.67 | Sub Total (19c) | | | | 5519.47 |

| | | | |
|---|---|---|---|
| Direct Cost per hr = | 3,035.51 | If manual | 2,353.97 |
| Profit & Over Head = | 758.88 | | 588.49 |
| Total Cost per m³ of concrete | **3,794.38** | | **3,923.28** |

Hourly Output **5.00** $M^3$/hr

**Work Item -20 C-20 Reinforced concrete (1:2:4)**

Equipment Output (1.8m³ Mixer)

Total Quantity Of Work Item 1m³

IF MANUAL **0.75** $M^3$/hr

| MATERIAL COST (a) | | | | | LABOUR COST (b) | | | | | EQUIPMENT COST (c) | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Type of Material** | **Unit** | **Qty** | **U.Price*** | **T.Cost** | **Trade** | **No** | **UF** | **Wage** | **Hourly** | **Equipment** | **No** | **UF** | **Rental** | **Hourly** |
| Cement | qts | 3.2 | 335.00 | 1072.00 | Forman | 1 | 1 | 47.92 | 47.92 | Simple Tools | 1 | 100% | 10 | 10.00 |
| Sand | m3 | 0.47 | 824.00 | 387.28 | Mason | 3 | 1 | 25.00 | 75.00 | Mixer | 2 | 100% | 1,522.00 | 3044.00 |
| Aggregate | m3 | 0.7 | 750.00 | 525.00 | Carpenter | 1 | 1 | 25.00 | 25.00 | Vibrator | 1 | 100% | 22.00 | 22.00 |
| Water | | | | 0.00 | Bar Bender | 1 | 1 | 25.00 | 25.00 | Loader | 1 | 100% | 2,025.33 | 2025.33 |
| | | | | | D/L | 22 | 1 | 10.00 | 220.00 | Shower Truck | 1 | 20% | 1,790.67 | 358.13 |
| | | | | | Con. Eng. | 1 | 0.15 | 64.58 | 9.69 | Service vehic. | 1 | 15% | 400.00 | 60.00 |
| | | | | | Site Manager | 1 | 0.05 | 81.25 | 4.06 | | | | | 0.00 |
| Sub Total (20a) | | | | 1984.28 | Sub Total (20b) | | | | 406.67 | Sub Total (20c) | | | | 5519.47 |

| | | | |
|---|---|---|---|
| Direct Cost per hr = | 3,169.51 | If manual | 2,487.97 |
| Profit & Over Head = | 792.38 | | 621.99 |
| Total Cost per m³ of concrete | **3,961.88** | | **4,146.61** |

Hourly Output **5.00** $M^3$/hr
Equipment Output (1.8m³ Mixer)
IF MANUAL **0.75** $M^3$/hr

**Work Item -21 C-25 Reinforced concrete**
Total Quantity Of Work Item 1m³

| MATERIAL COST (a) | | | | | LABOUR COST (b) | | | | | EQUIPMENT COST (c) | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Type of Material** | **Unit** | **Qty** | **U.Price*** | **T.Cost** | **Trade** | **No** | **UF** | **Wage** | **Hourly** | **Equipment** | **No** | **UF** | **Rental** | **Hourly** |
| Cement | qts | 3.6 | 335 | 1206.00 | Forman | 1 | 1 | 47.92 | 47.92 | Simple Tools | 1 | 100% | 10 | 10.00 |
| Sand | m3 | 0.47 | 824 | 387.28 | Mason | 3 | 1 | 25.00 | 75.00 | Mixer | 2 | 100% | 1,522.00 | 3044.00 |
| Aggregate | m3 | 0.7 | 750 | 525.00 | Carpenter | 1 | 1 | 25.00 | 25.00 | Vibrator | 1 | 100% | 22.00 | 22.00 |
| Water | | | | 0.00 | Bar Bender | 1 | 1 | 25.00 | 25.00 | Loader | 1 | 100% | 2,025.33 | 2025.33 |
| | | | | | D/L | 22 | 1 | 10.00 | 220.00 | Shower Truck | 1 | 20% | 1,790.67 | 358.13 |
| | | | | | Con. Eng. | 1 | 0.15 | 64.58 | 9.69 | Service vehic. | 1 | 15% | 400.00 | 60.00 |
| | | | | | Site Manager | 1 | 0.05 | 81.25 | 4.06 | | | | | 0.00 |
| Sub Total (21a) | | | | 2118.28 | Sub Total (21b) | | | | 406.67 | Sub Total (21c) | | | | 5519.47 |

| | | | |
|---|---|---|---|
| Direct Cost per hr = | 3,303.51 | If manual | 2,621.97 |
| Profit & Over Head = | 825.88 | | 655.49 |
| Total Cost per m³ of concrete | **4,129.38** | | **4,369.95** |

Hourly Output **5.00** $M^3$/hr
Equipment Output (1.8m³ Mixer)
If Manual **0.75** $M^3$/hr

**Work Item-22 C-30 Reinforced concrete (1:2:3)**
Total Quantity of Work Item 1m³

| MATERIAL COST (a) | | | | | LABOUR COST (b) | | | | | EQUIPMENT COST (c) | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Type of Material** | **Unit** | **Qty** | **U.Price*** | **T.Cost** | **Trade** | **No** | **UF** | **Wage** | **Hourly** | **Equipment** | **No** | **UF** | **Rental** | **Hourly** |
| Cement | qts | 4 | 335 | 1340.00 | Forman | 1 | 1 | 47.92 | 47.92 | Simple Tools | 1 | 100% | 10 | 10.00 |
| Sand | m3 | 0.47 | 824 | 387.28 | Mason | 3 | 1 | 25.00 | 75.00 | Mixer | 2 | 100% | 1,522.00 | 3044.00 |
| Aggregate | m3 | 0.7 | 750 | 525.00 | Carpenter | 1 | 1 | 25.00 | 25.00 | Vibrator | 1 | 100% | 22.00 | 22.00 |
| Water | | | | 0.00 | Bar Bender | 1 | 1 | 25.00 | 25.00 | Loader | 1 | 100% | 2,025.33 | 2025.33 |
| | | | | | D/L | 22 | 1 | 10.00 | 220.00 | Shower Truck | 1 | 20% | 1,790.67 | 358.13 |
| | | | | | Con. Eng. | 1 | 0.15 | 64.58 | 9.69 | Service vehic. | 1 | 15% | 400.00 | 60.00 |
| | | | | | Site Manager | 1 | 0.05 | 81.25 | 4.06 | | | | | 0.00 |
| Sub Total (22a) | | | | 2252.28 | Sub Total (22b) | | | | 406.67 | Sub Total (22c) | | | | 5519.47 |

| | | | |
|---|---|---|---|
| Direct Cost per hr = | 3,437.51 | If Manual | 2,755.97 |
| Profit & Over Head = | 859.38 | | 688.99 |
| Total Cost per m³ of concrete | **4,296.88** | | **4,593.28** |

Hourly Out Put **34.00** m²/hr
(Person Power)

**Work Item-23 Reinforcement Bar Work**
Total Quantity Of Work Item m²

| Material Cost (a) | | | | | Labour Cost (b) | | | | | Equipment Cost (c) | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Type of Material** | **Unit** | **Qty** | **U.Price*** | **T.Cost** | **Trade** | **No** | **UF** | **Wage** | **Hourly Cost** | **Type of Equt** | **No** | **UF** | **Rental** | **Hourly Cost** |
| Reinforcement Bar | Kg | 1.05 | 18.20 | 19.11 | Forman | 1 | 0.1 | 47.92 | 4.79 | Simple Tools | 1 | 100% | 5.26 | 5.26 |
| Tying Wire | Kg | 0.2 | 6.00 | 1.20 | Bar Bender | 2 | 1 | 25.00 | 50.00 | Welding Machine | 1 | 1 | 70.00 | 70.00 |
| | | | | | D.L | 4 | 1 | 10.00 | 40.00 | Service vehicle | 1 | 15% | 400.00 | 60.00 |
| | | | | | Construction Eng. | 1 | 0.15 | 64.58 | 9.69 | | | | | |
| Sub Total (55a) | | | | 20.31 | Sub Total (55b) | | | | 104.48 | Sub Total (55c) | | | | 135.26 |
| | | | | | Direct Cost per hr = | | | | 27.36 | | | | | |
| | | | | | Profit & Over Head = | | | | 6.84 | | | | | |
| | | | | | Total Cost per kg of bar | | | | 34.20 | | | | | |

Hourly Out Put **1.50** m²/hr
(Person Power)

**Work Item-24 Class-C HCB Wall (20cm thick)**
Total Quantity Of Work Item m²

| Material Cost (a) | | | | | Labour Cost (b) | | | | | Equipment Cost (c) | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Type of Material** | **Unit** | **Qty** | **U.Price*** | **T.Cost** | **Trade** | **No** | **UF** | **Wage** | **Hourly Cost** | **Type of Equt** | **No** | **UF** | **Rental** | **Hourly Cost** |
| HCB | No. | 13 | 15.00 | 195.00 | Forman | 1 | 0.05 | 47.92 | 2.40 | Simple Tools | 1 | 100% | 5.26 | 5.26 |
| Cement | qntl | 0.1 | 335.00 | 33.50 | Mason | 1 | 1 | 25.00 | 25.00 | | | | | 0.00 |
| Sand | m3 | 0.028 | 824.00 | 23.07 | Laborer | 2 | 1 | 10.00 | 20.00 | Service vehicle | 1 | 15% | 70.00 | 10.50 |
| Water | m3 | 0.3 | 0 | 0.00 | Con.Eng. | 1 | 0.01 | 64.58 | 0.65 | | | | | |
| | | | | | surveyor | 1 | 0.1 | 52.08 | 5.21 | | | | | |
| Sub Total (55a) | | | | 251.57 | Sub Total (55b) | | | | 53.25 | Sub Total (55c) | | | | 15.76 |
| | | | | | Direct Cost per hr = | | | | 297.58 | | | | | |
| | | | | | Profit & Over Head = | | | | 74.39 | | | | | |
| | | | | | Total Cost per m² of HCB work | | | | 371.97 | | | | | |

*Note: These tables and additional work items are presented in template excel table. Thus, one can refer details of these tables and for other items there.*

## 3.6 SUMMARY OF UNIT RATE ANALYSIS (URA) PROCEDURE

The URA consists of individual work sheets for each BOQ work item. Use the following procedure to prepare data.

a) The first step is to compile the Basic Cost Data as thoroughly as possible. Note that the Basic Cost Data is the most important part of the entire costing exercise as the final contract sum is directly proportional to the accuracy of the Basic Cost Data. Hence, the Basic Cost Data compilation is, necessarily, the most difficult and time-consuming stage of the costing exercises;
b) Decide on the most appropriate choice of technology (using labour or using equipment) for implementation of each BOQ work item. The appropriate choice can only be made if one has acquired sufficient knowledge of the prevailing conditions on site;
c) Decide what activities need to be carried out and what resources are required to implement the BOQ item taking into account the selected technology;
d) Based on your knowledge of the prevailing conditions on site, decide on the productivity rates to be applied on the labour & equipment activities, and estimate the quantities of materials to produce one unit of the bill item. Note that productivities of labour, in particular, may vary considerably depending on the prevailing site conditions, hence the importance of familiarizing oneself with the local conditions;
e) The final stage in this process is to transfer the relevant data from the Basic Cost Data and calculate the unit rates for each item.

The following steps are very important to enter data to the analysis sheet and calculate the unit rate of each BOQ item.

a) Decide the crew composition and productivity and enter the crew output;
b) List the types of materials, quantity required for a unit of work and the prices of the materials;
c) In the labour cost part of the worksheet, list the types of labour required and enter their utilization factor and the indexed daily costs;
d) In the equipment part of the worksheet, list the required equipment, their utilization factor and the daily costs of the equipment;
e) Calculate the material, labour and equipment costs. Here, since the materials are for a unit of work, no need to divide by the crew output. On the other hand, the total labour and equipment costs should be divided by the crew output to get the labour and equipment cost for a unit of work item;
f) At this step sum up the material, labour and equipment cost which will give you the total direct cost;
g) Calculate the overhead cost based on the result obtained from step “f” and add this value on the direct cost to get the sum of direct cost and overhead cost;
h) Add appropriate profit margin on the value obtained in step “g” and this will be the total cost for BOQ item under consideration.

For each BOQ work item, the user is then required to work out the unit rates following the corresponding URA sheet. The format of the URA sheet is shown above. The URA sheet is basically divided into 2 sections namely the Direct Costs and the Indirect Costs.

**Direct Cost**: The direct cost as calculated in the URA sheet is the net unit rate. The net unit rates are used to calculate the total direct costs of the job in order that total overhead costs can be expressed as a % of these direct costs. This percentage is then applied back onto all work items as the overheads on each item.

**Indirect Costs**: The indirect costs include overheads, risk and profit. The sum total of direct & indirect costs is the Gross Unit Rate, which appears at the bottom of the URA sheet as the Total item. The gross unit rate is the final unit rate that is transferred to the particular item of work.

# 4 PROJECT COST ESTIMATION

## 4.1 COMPONENTS OF PROJECT COST

Irrigation project's construction cost includes:

- Materials purchase and/or rental cost on the project site,
- Equipment purchase and/or rental cost,
- Transportation cost:
- For fetching construction materials stated above.
- Disposing unwanted/excess material, etc.
- Professional cost:
- Team leader,
- Resident Engineer,
- Project Manager,
- Construction engineer,
- Forman, etc.
- Labour (skilled/Unskilled) cost includes:
- Loading/unloading,
- Daily labourer,
- Mason
- Assistant mason,
- Carpenter,
- Bar bender, etc.

In addition to this, project cost should also include:

- Taxes (VAT), 15% of engineers estimate
- Management & construction supervision cost, 5-10% of engineers estimate
- Physical contingencies for unforeseen items of work, 5-10% of engineers estimate

## 4.2 CONSIDERATIONS IN PROJECT COST ESTIMATE

Project cost estimate, which is considered as the engineers estimate, should be prepared based on the detailed Bill of Quantities and up-to-date rate for construction and procurements and/or rental services.

As project cost provides basis for determining project's economic and financial viability and their financial funding, this shall be taken in to consideration for its best estimation right from bills of items and rate establishment. Such estimates thus will include all capital costs and incremental operating costs incurred by the project during the disbursement period and for the subsequent operation of the project.

In principle, the engineering cost estimates should include all incremental goods and services required to complete the planned works. Cost estimates for the main civil engineering works should therefore be based on Bills of Quantities (BOQ), derived from detail designs and justified unit rates.

Costs of major equipment items based on recent quotations from potential suppliers shall be presented. Costs of on-farm development may be drawn from an aggregation of representative

farm models but it shall clearly indicate whether these include cash or non-cash contributions (e.g. in the form of family labour or locally available materials) by beneficiaries.

Cost estimates of an acceptable format shall be prepared for all the proposed works considered at the final detailed design with schedules of expenditure.

The prepared bill of quantity and engineering cost estimate of each work item should show how the project specific bills of quantity such as:

- Work classification sections,
- Consecutive numbering and referring system,
- Addition of new items, and addition of new sections,
- Consistency of items in the BOQ with that used in design and drawing, etc. based upon the drawings and specification information prepared specifically for this purpose.

## 4.3 UNIT COSTS OF IRRIGATION PROJECTS

Unit cost of irrigation projects is a measure of expensiveness or cheapness of a certain project. It is represented in terms of lump-sum cost/hectare of that particular project.

For small scale irrigation projects, these costs vary from project to project and from location to location as well as from time to time depending on market conditions.

# 5 CONCLUSION AND RECOMMENDATION

The analyzed breakdowns of unit rates show that market prices of the following items play the most governing role in construction industry:

- Equipment Rental cost;
- Fuel cost
- Construction material procurement & transportation cost like Cement and Reinforcement bars, etc.
- Salaries of staffs and daily labourer cost.

Mistakes in the bill descriptions or quantities are unlikely to be remedied as a legal rectification of the terms of the contract to reflect the true intention of the parties. It is more likely than not, that the common intention will be that the tendered price should prevail, rather than a price revised to account of the error. Most standard forms of contract which adopt Bills of Quantities make provision to deal with errors in bill descriptions and quantities, distinct from the effect of variations.

Construction industry is facing a number of complicatedness with the growing needs in terms of safety, quality, productivity, technology, and foreign competition. Thus, stepping forward with such governing and other external factors will at all-time demand for getting up-to-date rate of these work items and timely considerations.

The currently established norms are also typically based on presently existing situations and normal/safe working conditions, such as 8 working hours per day, required workmanship is maintained, no conflict which can hinder/interrupt the daily output, no external influential factors like torrential rain, flooding, etc. However, the implementer can improve this set standard by employing interested workers for overtime and shorten critical paths. This can also be achieved through piece rating of works and initiating participants on that project.

This unit rate standard for civil works of water resources development activities is established in such a way that it can absorb possible elements of work items and requires only updating cost of inputs which in-fact is changing at the fastest rate with the dynamically changing construction materials market conditions.

Manpower resources on construction activities be professionals or daily laborers, are turning over/moving at faster rate than what had been observed before, depending on market conditions. Thus, so as to stay in a competition environment and retain experts with the implementer or stabilize them, some motivation specifically for the competent performers needs to be put into practice. This in-fact has advantage over hiring new professionals in that experience of existing staffs especially on water works cannot be built in shorter time. Thus, to maintain current quality of water works and unspoiled construction environment, the implementer shall preserve experienced staffs to the maximum as possible.

Market rate of construction materials should also be studied and revised just before implementation of the project is continuing. This could be done by a team established from different sections like engineering, accounting, and other concerned sections if any.

In the current competition environments, it is a fact that, piece rating or contracting the work out could be advantageous both for the client and the workers themselves. On the other hand, client's construction engineers do have fear in maintaining currently developed quality of work experience. The consultant however believes this fear can be managed through regular follow up. Therefore, piece rating is the best option so as to do large volume of work with its required quality provided every expected follow up is maintained.

It is a fact that, most development organizations be it a Government or an NGO, have been adopting a cost sharing policy towards their community development projects. The reason is that if communities have to pay for at least part of the project cost, they are more likely to value the facility and feel a sense of ownership. Thus the consultant recommends this mechanism whatsoever the living standard of beneficiaries be; because it can keep not only sense of rightness but also have positive impact on operation and maintenance of schemes. The willingness and ability to pay a cost contribution however varies from community to community and should be assessed carefully. The actual community contribution should be negotiated with the community and not determined by an external agency/body.

So as to make cost recoverable schemes, site management should maximize income and also minimize costs but maintaining quality of work to the required degree. Good planning for that matter avoid crisis management, making the correct choice of methods, good equipment and material management, good quality control and good relations with the workforce which thus minimize costs and hence maximize profits of-course within the scope/objectives of the client. The consultant also recommends ensuring correct measurement and claims so as to increase production and hence maximize income.

This cost recoverable rate could be prepared in two ways: either by analyzing current market situation and then establish the new rate that can recover any cost and related expenses or analyzing existing working rates that the client is applying at the moment, based on which new rate can be established so that it is cost recoverable rate. However, sufficient and quality data could not be accessed on surface construction aspects. Thus, the former approach shall be taken up in establishing new rates of work items. The computed results shall be compared with government, semi-government and non-governmental organizations, which will accordingly enable its proficiency/rationality.

# REFERENCES


- Design Standards on Technical Specification, MoWR, 2002.
- Component V: Part A-Conditions of Contract, Tender Dossier, Contract Document Preparation & Evaluation of Contractors, ESRDC, 1997.
- Guide to tools and equipment for labour-based construction. ILO, Geneva, 1981
- Module-11: Training Material for Unit Rate Analysis, BOQ & Cost Estimate for AGP SSIP, GIRDC, 2015.
- Productivity norms for labour based construction, ILO, Advisory Support, Information Services and Training (ASIST), Kenya, 2015.
- Project Administration Handbook for Civil Engineering Works, 2016.


**Web sites**


- https://theconstructor.org/practical-guide/methods-units-of-measurements,
- https://en.wikipedia.org/wiki/Engineering_tolerance,
- https://www.quora.com,
- http://www.engineeringcivil.com/what-are-the-tolerance-limits-on-construction,

# APPENDICES

## APPENDIX I: Tolerance Limits of Different Materials on Construction Site

As per the web site "https://en.wikipedia.org/wiki/Engineering_tolerance", the followings can be used as tolerance limit guides for civil works in construction industry.

**i/ Accuracy of measuring equipment in batching plant.**
Cement: + – 2%
Aggregate: + – 3%
Admixture: + – 3%
Water: + – 3%
Mixing time: 2 minutes for one mixing. (Mixing which is being done on site)

**ii/ Tolerance in Form work**
In C/S for columns & Beams deviation is = + 12mm more (or) – 6mm less in size
In footing plan = + 50 mm more (or) – 12 mm less size
In depth = + – 0.05 D (specified thickness).

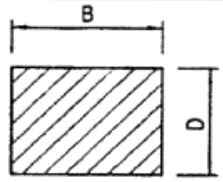
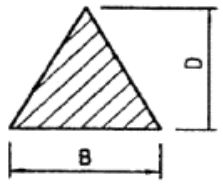
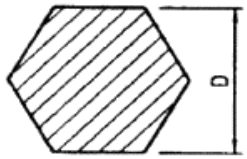
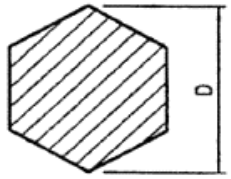
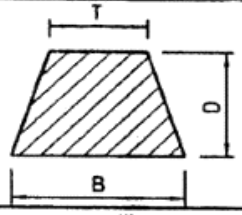
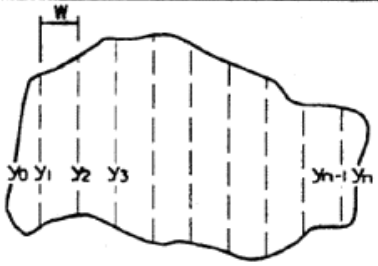
**iii/ Tolerance in Reinforcement**
For effective depth D < = 200mm = +- 10mm; for effective depth D > 200mm = +- 15mm
For Cover to reinforcement = + 10mm
Maximum free-fall of concrete = 1.50 m height.

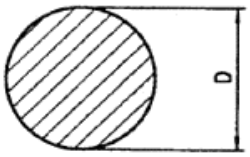
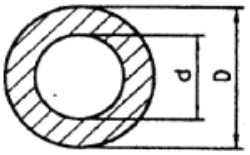
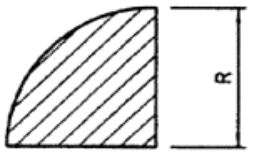
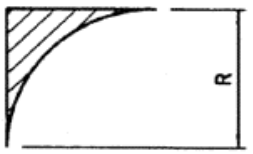
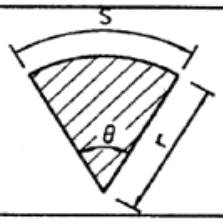
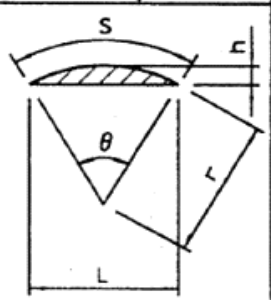
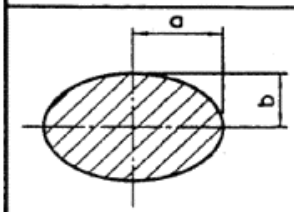
**iv/ Tolerance on diameter in length**
0-25mm = +- 0.5 %
25-35mm = +- 0.6 %
35-50mm = +- 0.8 %

**v/ Tolerance on weight per meter**
0-10mm = +- 7%
10-16mm = +- 5%
16 and above = +- 3%

**vi/ Tolerance for cutting Length**
A) When the specified length is not given = + 75mm (or) – 25 mm
B) When the minimum length is specified = + 50 mm (or) – 0 mm

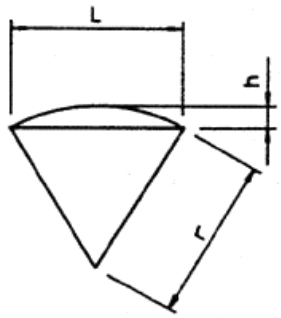
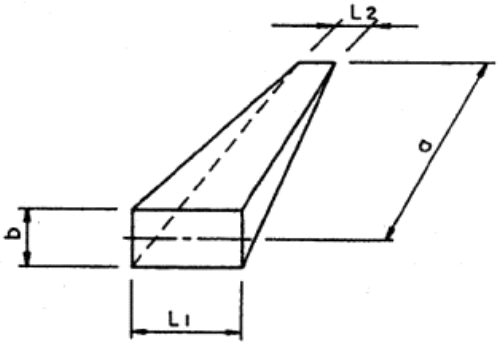
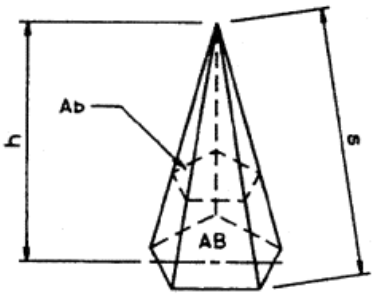
**APPENDIX II: Measurements Formulae of Area**

| SECTION | AREA |
|---|---|
|   | $A = B \times D$ |
|   | $A = \frac{BD}{2}$ |
|   | $A = 0.866\ D^2$ |
|   | $A = 0.65\ D^2$ |
|   | $A = \frac{D\ (T + B)}{2}$ |
|   TRAPEZOIDAL RULE:- $A = W\left[\frac{Y_0+Y_n}{2} + Y_1+Y_2+\ldots\ldots\ldots+Y_{n-1}\right]$ SIMPSON'S RULE:- ( n MUST BE EVEN ) $A = \frac{W}{3}[(Y_0+Y_n)+4(Y_1+Y_3+\ldots\ldots\ldots+Y_{n-1})+2(Y_2+Y_4+\ldots\ldots\ldots+Y_{n-2})]$ | |

| SECTION | AREA |
|---|---|
|   | $A = 0.7854\ D^2$ |
|   | $A = 0.7854(D^2-d^2)$ |
|   | $A = 0.7854\ R^2$ |
|   | $A = 0.2146\ R^2$ |
|   | $A = \frac{\theta}{360} \times \pi r^2$ $A = \frac{\theta}{360} \times 3.14 r^2$ $= \frac{sr}{2}$ |
|   | A = AREA OF SEGMENT = AREA OF SECTOR- AREA OF TRIANGLE $= \frac{1}{2}[sr \pm L(r-h)]$ ( - If $h \leq r$ ; + If $h \geq r$ ) or $A = \frac{2Lh}{3}$ ( APPROX. FORMULA ) |
|   | $A = \pi ab$ $= 3.14ab$ |

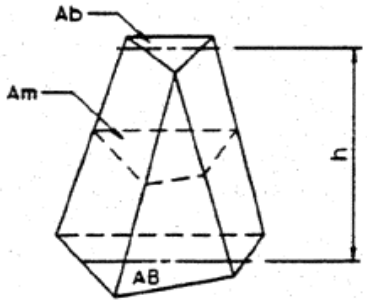
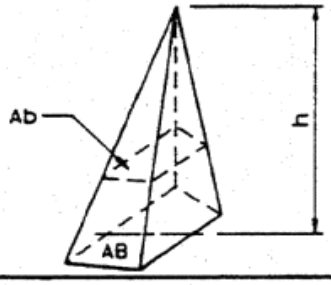
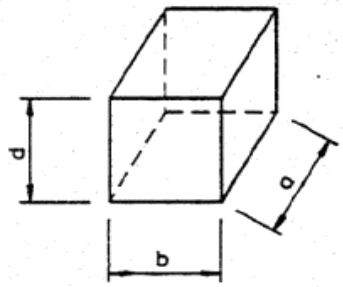
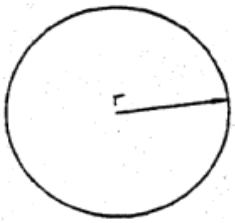
Source: PAH, 2016

**APPENDIX III: Measurements Formulae of Volume**

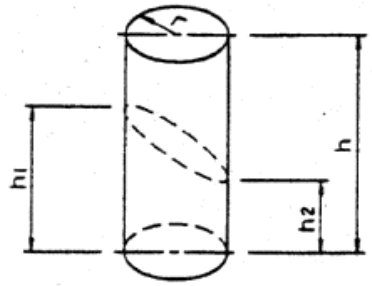
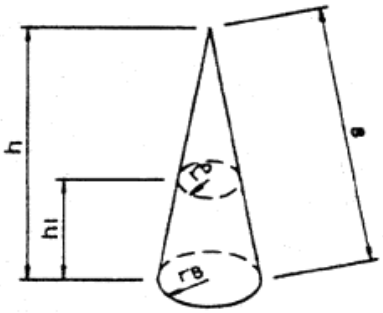
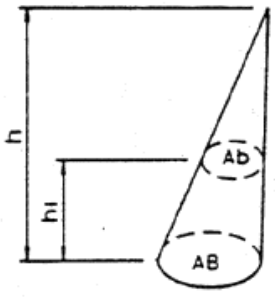
| SHAPE | VOLUME |
|---|---|
| SPHERICAL SECTOR<br>( AND HEMISPHERE )<br>  <br> | FOR SPHERICAL SECTOR:<br>$A_T = \frac{\pi r}{3}(4h+L)$;<br>$V = \frac{2\pi r^2 h}{3}$<br>FOR HEMISPHERE<br>( LETTING $h=\frac{L}{2}=r$ );<br>$A_T = 3\pi r^2$;<br>$V = \frac{2\pi r^3}{3}$ |
| WEDGE<br>( AND RIGHT TRIANGULAR PRISM )<br>  <br> | FOR WEDGE<br>( NARROW SIDE RECTANGULAR ):<br>$V = \frac{ab}{6}(2L_1+L_2)$<br>FOR RIGHT TRIANGULAR PRISM<br>( OR WEDGE HAVING PARALLEL TRIANGULAR BASES PERPENDICULAR TO SIDES )<br>$L_2 = L_1 = L$ :<br>$V = \frac{abL}{2}$ |
| RIGHT REGULAR PYRAMID<br>( AND FRUSTUM OF RIGHT REGULAR PYRAMID )<br>  <br> | FOR RIGHT REGULAR PYRAMID:<br>$A_L = \frac{sPB}{2}$;<br>$V = \frac{hAB}{3}$<br>FOR FRUSTUM OF REGULAR PYRAMID:<br>$A_L = \frac{s}{2}(PB+Pb)$<br>$V = \frac{h}{3}(AB+Ab+\sqrt{AB\ Ab})$ |

NOTATION : LINES, a, b,.....; ALTITUDE ( PERPENDICULAR HEIGHT ), h, h .....; SLANT HEIGHT, s; RADIUS, r; PERIMETER OF BASES, Pb OR PB ; CHORD OF SEGMENT, L; RISE, h; AREA OF BASE, Ab OR AB ; TOTAL AREA OF CONVEX SURFACE, $A_L$ ; TOTAL AREA OF ALL SURFACES, $A_T$ ; VOLUME, V.

Source: PAH, 2016

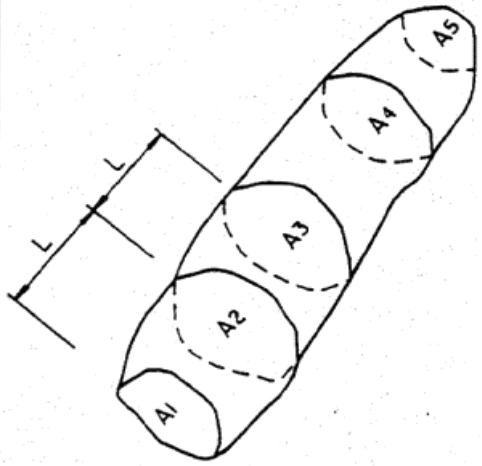
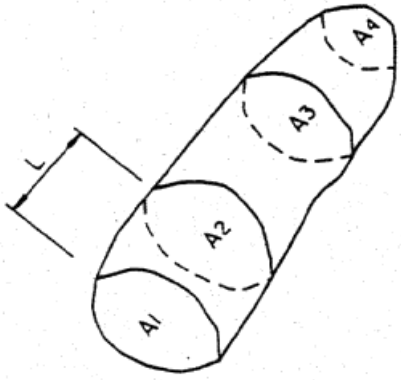
| SHAPE | VOLUME |
|---|---|
| PRISMATOID   | LET AREA OF MID-SECTION = A<br>$V = \frac{h}{6}(AB+Ab+4Am)$ |
| GENERAL PYRAMID<br>( AND FRUSTUM OF PYRAMID )   | FOR GENERAL PYRAMID:<br>$V = \frac{hAB}{3}$<br>FOR FRUSTUM OF GENERAL PYRAMID:<br>$V = \frac{h}{3}(AB+Ab+\sqrt{AB\ Ab})$ |
| CUBIC   | V = a.b.d |
| SPHERE   | LET DIAMETER = d<br>$A_T = 4\pi r^2 = \pi d^2$<br>$V = \frac{4\pi r^3}{3} = \frac{\pi d^3}{6}$ |
| NOTATION : LINES, a, b.....; ALTITUDE ( PERPENDICULAR HEIGHT ), h, h .....; SLANT HEIGHT, s; RADIUS, r; PERIMETER OF BASES, Pb OR PB ; CHORD OF SEGMENT, L; RISE, h; AREA OF BASE, Ab OR AB ; TOTAL AREA OF CONVEX SURFACE, AL ; TOTAL AREA OF ALL SURFACES, $A_T$ ; VOLUME, V. | |

Source: PAH, 2016

| SHAPE | VOLUME |
|---|---|
| RIGHT CIRCULAR CYLINDER<br>( AND TRUNCATED RIGHT<br>CIRCULAR CYLINDER )<br>  <br> | FOR RIGHT CIRCULAR CYLINDER:<br>$AL = 2\pi rh$;<br>$At = 2\pi r(r+h)$;<br>$V = \pi r^2 h$<br>FOR TRUNCATED RIGHT CIRCULAR CYLINDER:<br>$AL = \pi r(h_1 + h_2)$;<br>$At = \pi r[h_1 + h_2 + r + \sqrt{r^2 + (\frac{h_1 - h_2}{2})^2}]$;<br>$V = \frac{\pi r^2}{2}(h_1 + h_2)$ |
| RIGHT-CIRCULAR CONE<br>( AND FRUSTUM OF RIGHT<br>CIRCULAR CONE )<br>  <br> | FOR RIGHT CIRCULAR CONE:<br>$AL = \pi rBs = \pi rB\sqrt{rB^2 + h^2}$;<br>$At = \pi rB(rB+s)$;<br>$V = \frac{\pi rB^2 h}{3}$<br>FOR FRUSTUM OF RIGHT CIRCULAR CONE:<br>$s = \sqrt{h_1^2 + (rB-rb)^2}$;<br>$At = \pi s(rB+rb)$;<br>$V = \frac{\pi h_1}{3}(rB^2 + rb^2 + rBrb)$ |
| GENERAL CONE<br>( AND FRUSTUM OF GENERAL CONE )<br>  <br> | FOR GENERAL CONE:<br>$V = \frac{ABh}{3}$<br>FOR FRUSTUM OF GENERAL CONE:<br>$V = \frac{h_1}{3}(AB + Ab + \sqrt{ABAb})$ |

NOTATION : LINES, a, b,.....; ALTITUDE ( PERPENDICULAR HEIGHT ), h, h ,.....; SLANT HEIGHT, s; RADIUS, r; PERIMETER OF BASES, Pb OR PB ; CHORD OF SEGMENT, L; RISE, h; AREA OF BASE, Ab OR AB ; TOTAL AREA OF CONVEX SURFACE, AL ; TOTAL AREA OF ALL SURFACES, At ; VOLUME, V.

Source: PAH, 2016

| SHAPE | VOLUME |
|---|---|
| IRREGULAR SHAPE   | L = THE DISTANCE BETWEEN THE SECTIONS<br>A1, A2, A3, A4 & A5 = THEIR AREAS<br>$V = \frac{L}{3}(A1 + 4A2 + 2A3 + 4A4 + A5)$<br>N. B.<br>AN ODD NUMBER OF SECTIONS ARE REQUIRED FOR APPLICATION OF THIS RULE<br>SIMPSON'S RULE |
| IRREGULAR SHAPE   | L = THE DISTANCE BETWEEN THE SECTIONS<br>A1, A2, A3 & A4 = THEIR AREAS<br>$V = L(\frac{A1 + A4}{2} + A2 + A3)$<br>METHOD OF END AREAS |

Source: PAH, 2016

## APPENDIX IV: Recommended Work Norms of Different Activities

Recommended Work Norms for Site Clearing

| Average productivity by type of cover ($m^2$/day) | | | |
|---|---|---|---|
| Dense bush | Medium bush | Light bush | Grubbing |
| 100 | 200 | 350 | 175 |

Source: ILO, ASIST, Kenya, 2015

Recommended Work Norms for Excavation

| Average productivity by Soil Classification ($m^3$/day) | | | | |
|---|---|---|---|---|
| Soft | Medium | Hard | Very hard | Rock |
| 5 | 3.5 | 3.0 | 2.0 | 0.80 |

Source: ILO, ASIST, Kenya, 2015

Recommended Haulage Norms by Wheelbarrow

| Wheelbarrow Haulage Norms by Haul Distance ($m^3$/day) | | | | | |
|---|---|---|---|---|---|
| 0-20m | 20-40m | 40-60m | 60-80m | 80-100m | 100-150m |
| 8.5 | 7.0 | 6.5 | 5.5 | 5.0 | 4.5 |

Source: ILO, ASIST, Kenya, 2015

Recommended Loading, Unloading and Spreading Norms

| Average productivity Rates ($m^3$/day) | | |
|---|---|---|
| Dense bush | Medium bush | Light bush |
| 8.5 | 10 | 13.5 |

Source: ILO, ASIST, Kenya, 2015

Recommended Compaction Norms

| Manual compaction, $m^3$/d | Equipment compaction, $m^2$/ roller day |
|---|---|
| 9.0 | 700 |

Source: ILO, ASIST, Kenya, 2015

Recommended Culvert Laying & Related Works Norms

| Culvert installation, m/day | Concrete work, $m^3$/d | Masonry work, $m^3$/d |
|---|---|---|
| 0.9 | 1.0 | 1.0 |

Source: ILO, ASIST, Kenya, 2015

# SSIGL 20

Prepared by

GIRDC