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Advanced Construction Technology

现代施工技术

（原书第四版）

[英] Roy Chudley
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Xiandai Shigong Jishu
[英]Roy Chudley　Roger Greeno
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PREFACE TO THIRD EDITION

Roy Chudley's *Construction Technology* was first published in four volumes, between 1973 and 1977. The material has since been continuously updated through numerous reprints and full second editions in 1987. The books have gained a world-wide readership, and their success-and their impact on construction education-is a tribute to Roy Chudley's experience in further and higher education and his talents as a skilled technologist, illustrator and writer.

As a former colleague, it has been a privilege to once again work with Roy, on this occasion revising his original work, and compiling the material into two books: *Construction Technology* and *Advanced Construction Technology*. The content forms a thorough study for all students of building, construction management, architecture, surveying and the many other related disciplines within the diverse construction profession.

The original presentation of comprehensive text matched by extensive illustration is retained. Changes in legislation, such as the Building and Construction Regulations, have been fully incorporated into the text; however, as much of the original work as possible has been purposely retained as it contains many relevant examples of existing construction. Additional material discusses the new developments and concepts of contemporary practice.

The two new volumes are complementary, as many of the topics introduced in *Construction Technology* are further developed here. Together the books provide essential reading for all students aspiring to management, technologist and professional qualifications. They should be read alongside the current local building regulations and national standards, and where possible supplemented by direct experience in the workplace.

Roger Greeno
Guildford 1998

PREFACE TO FOURTH EDITION

Since the previous edition, reprint opportunities have permitted some amendments. These have included new procedures, relative to legislative and practice changes. This revised edition develops these further, with greater attention to information and detail. It also incorporates more recent issues, especially aspects of the Building Regulations that require buildings to be designed and constructed to higher energy-efficient standards. The responsibilities on building designers and owners with regard to human rights are considered in a new chapter outlining the facilities required for the convenience of the less able using buildings other than dwellings.

Notwithstanding contemporary requirements, the book's established construction principles are retained. These provide a useful reference to existing building stock, and, where appropriate, modifications are included to illustrate ongoing change.

The content represents the basic elements of construction practice. The book is neither extensive nor prescriptive, as there is insufficient space in any book to include every possible means for constructing commercial and industrial buildings. However, the content is generally representative, and the reader is encouraged to develop their knowledge through experiential learning, observation in the workplace, and reading manufacturer's literature and technical articles in professional journals. Reference sources for supplementary reading are provided throughout.

In conjunction with this edition's companion volume, *Construction Technology*, the reader should gain an appreciation of the subject material to support progression through any technical, academic or professional qualification study programme that includes construction as core or supplementary modules.

Roger Greeno
Guildford 2006

ACKNOWLEDGEMENTS

This book originated in the 1970s as part of a four-volume series written by Roy Chudley. As a result of its popularity, numerous reprints and a new edition followed. In 1998 the series was rewritten by Roger Greeno as two separate volumes: the initial two volumes formed the basis for the companion title, *Construction Technology*, and the remainder *Advanced Construction Technology*.

The book's endurance is a tribute to Roy's initial work in representing construction practice with comprehensive illustrative guidance and supporting text. I am particularly grateful to the founding author for allowing me the opportunity to continue this work and to emulate his unique presentation. I am also grateful to the late Colin Bassett as general editor. It was his initiative and enthusiasm that encouraged me to pursue this work.

No book can succeed without a good publisher, and Pearson Education have fulfilled that role with their supportive editorial and production team. In particular, Pauline Gillett has been a constant source of direction and help throughout the preparation of the manuscript.

Roger Greeno
Guildford 2006

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INTRODUCTION

Advanced Construction Technology is a development of the relatively elementary construction detailed in the associated volume, *Construction Technology*. This volume augments the associated volume with further topics relating to domestic buildings and lightweight-framed structures, in addition to concentrating primarily on complex and specialised forms of construction.

It is designed to supplement a student's lecture notes, projects and research assignments as well as to provide a valuable professional reference. It also complements the associated subjects of science, mathematics, materials technology, design procedures, structural analysis, structural design, services, quantity surveying, facilities management and management studies, and is therefore appropriate for most undergraduate and higher-level construction study programmes.

The format adopted follows that of *Construction Technology*, providing concise notes and generous illustrations to elaborate on the text content. The reader should appreciate that the illustrations are used to emphasise a point of theory and must not be accepted as the only solution. A study of working drawings and details from building appraisals given in the various construction journals will add to background knowledge and comprehension of construction technology.

No textbook or work of reference is ever complete. Therefore readers are recommended to seek out all sources of reference on any particular topic of study, to maximise information and to gain a thorough comprehension of the subject. Construction technology is not purely academic; lectures and textbooks can only provide the necessary theoretical background to the building processes of design and site application. Practical experience and monitoring of work in progress are essential components of any study programme involving the subject of construction technology.

CONTENTS

PART 1

PLANT AND EQUIPMENT

1.1 BUILDERS' PLANT: GENERAL CONSIDERATIONS

The general aim of building is to produce a structure at reasonable cost and of sound workmanship within an acceptable time period. To achieve this time period and in many cases to overcome a shortage of suitable manpower the mechanisation of many building activities must be considered. The range of plant now available to building contractors is very extensive, ranging from simple hand tools to very expensive equipment that undertakes tasks beyond the capabilities of manual labour. In a text of this nature it is possible only to consider the general classes of plant and their uses; for a full analysis of the many variations, with the different classifications, readers are advised to consult the many textbooks and catalogues devoted entirely to contractors' plant.

The main reasons for electing to use items of plant are as follows:

- Increase rate of output.
- Reduce overall building costs.
- Carry out activities that cannot be done manually or do them more economically.
- Eliminate heavy manual work, thus reducing fatigue and increasing the productivity of manual workers.
- Maintain a planned rate of production where there is a shortage of either skilled or un-

skilled operatives.

- Maintain the high standards often required by present-day designs and specifications, especially when concerned with structural engineering works.

It must not be assumed that the introduction of plant to a contract will always reduce costs. This may well be true with large contracts, but when carrying out small contracts such as a traditionally built one-off house it is usually cheaper to carry out the constructional operations by traditional manual methods: the main exception to this is the mixing of concrete and cement mortar using a small mobile batch mixer.

The type of plant to be considered for selection will depend upon the tasks involved, the time element, and the staff available. The person who selects the plant must be competent, the plant operator must be a trained person to obtain maximum efficiency, the manufacturer's recommended maintenance schedule for the plant must be followed and, above all, the site layout and organisation must be planned with a knowledge of the capabilities and requirements of the plant.

Having taken the decision to use plant and equipment, the contractor now has the choice of buying, hiring or combining the two. The advantages of buying plant are as follows:

- Plant is available when required.
- The cost of idle time caused by inclement weather, work being behind planned programme or delay in deliveries of materials will generally be less on owned plant than on hired plant.
- The builder can apportion the plant costs to the various contracts using the plant, by his/her own chosen method.
- There is some resale value.

The advantages of hiring plant are as follows:

- Plant can be hired as required and for short periods.
- Hire firms are responsible for maintenance, repairs and replacements.
- The contractor is not left with unused expensive plant items after completion of the contract.
- Hire rates can include operator, fuel and oil.

To be an economic proposition large items of plant need to be employed continuously and not left idle for considerable periods of time. Careful maintenance of all forms of plant is of the utmost importance. This not only increases the working life of a piece of plant, but if a plant failure occurs on site it can cause serious delays and disruptions of the programme, and this in turn can affect the company's future planning. To reduce the risk of plant breakdown a trained

and skilled operator should be employed to be responsible for the running, cleaning and daily maintenance of any form of machinery. Time for the machine operator to carry out these tasks must be allowed for in the site programme and the daily work schedules.

On a large contract where a number of machines are to be employed, a full-time skilled mechanic could be engaged to be responsible for running repairs and recommended preventive maintenance. Such tasks would include:

- checking oil levels-daily;
- greasing-daily or after each shift;
- checking engine sump levels-after 100 hours' running time;
- checking gearbox levels-after 1,200 to 1,500 hours' running time;
- checking tyre pressures-daily;
- inspecting chains and ropes-daily.

As soon as a particular item of plant has finished its work on site it should be returned to the company's main plant yard so that it can be re-allocated to another contract. This is equally important for hired plant, which must be returned to the hire company's depot; otherwise excess charges may apply. On its return to the main plant yard or hire depot an item of plant should be inspected and tested so that any necessary repairs, replacements and maintenance can be carried out before it is re-employed on another site. A record of the machine's history should be accurately kept and should accompany the machine wherever it is employed so that the record can be kept up to date.

The soil conditions and modes of access to a site will often influence the choice of plant items that could be considered for a particular task. Congested town sites may severely limit the use of many types of machinery and/or plant. If the proposed structure occupies the whole of the site, component and material deliveries in modules or prefabricated format will eliminate the need and space for fabrication and assembly plant. Concrete-mixing plant will also be impractical; therefore supplies will be delivered ready mixed. Wet sites usually require plant equipped with caterpillar tracks, whereas dry sites are suitable for tracked and wheeled vehicles or power units. On housing sites it is common practice to construct the estate road sub-layers at an early stage in the contract to provide firm access routes for mobile plant and hard-standing for static plant such as cement mixers. Sloping sites are usually unsuitable for rail-mounted cranes, but these cranes operating on the perimeter of a building are more versatile than the static cranes. The heights and proximity of adjacent structures or buildings may limit the use of a horizontal jib crane and may even dictate the use of a crane with a luffing jib.

For accurate pricing of a bill of quantities careful consideration of all plant requirements must be undertaken with the preparation of a plant schedule at the pre-tender stage. This

should take into account plant types, plant numbers and personnel needed. If the tender is successful a detailed programme should be prepared in liaison with all those to be concerned in the supervision of the contract so that the correct sequence of operations is planned and an economic balance of labour and machines is obtained.

Apart from the factors previously discussed, consideration must also be given to safety and noise emission requirements when selecting items of plant for use on a particular contract. The aspects of safety that must be legally provided are contained in various Acts of Parliament and Statutory Instruments such as the Health and Safety at Work etc. Act 1974, the Construction (Health, Safety and Welfare) Regulations 1996 and the Noise at Work Regulations 1989. These requirements will be considered in the following chapters devoted to various classifications of plant.

Although reaction to noise is basically subjective, excessive noise can damage a person's health and/or hearing; it can also cause disturbance to working and living environments. Under the Health and Safety at Work etc. Act 1974 and its subsidiary regulations provision is made for the protection of workers against noise. If the maximum safe daily noise limits for the unprotected human ear are likely to be exceeded, the remedies available are the issue of suitable ear protectors to the workers, housing the plant in a sound-insulated compartment, or the use of quieter plant or processes.

1.2 EARTH-MOVING AND EXCAVATION PLANT

The selection, management and maintenance of builders' plant are particularly important when considered in the context of earth-moving and excavation plant. Before deciding to use any form of plant for these activities the site conditions and volume of work entailed must be such that it will be an economic venture. The difference between plant that is classified as earth-moving equipment and excavating machines is very slight, because a piece of plant that is designed primarily to excavate will also be capable of moving the spoil to an attendant transporting vehicle, and, likewise, machines basically designed to move loose earth will also be capable of carrying out excavation works to some degree.

To browse through the catalogues of plant manufacturers and hirers to try and select a particular piece of plant is a bewildering exercise because of the wide variety of choice available for all classes of plant. Final choice is usually based upon experience, familiarity with a particular manufacturer's machines, availability or personal preference. There are many excellent works of reference devoted entirely to the analysis of the various machines to aid the would-be buyer or hirer; therefore in a text of this nature it is necessary only to consider the general

classes of plant, pointing out their intended uses and amplifying this with typical examples of the various types without claiming that the example chosen is the best of its type but only representative.

BULLDOZERS AND ANGLEDOZERS

These machines are primarily a high-powered tractor with caterpillar or crawler tracks and fitted with a mould board or blade at the front for stripping and oversite excavations up to a depth of 400 mm(depending upon machine specification) by pushing the loosened material ahead of the machine. For backfilling operations the angledozer with its mould board set at an angle, in plan, to the machine's centreline can be used. Most mould boards can be set at an angle in either the vertical or the horizontal plane to act as an angledozer, and on some models the leading edge of the mould board can be fitted with teeth for excavating in hard ground. These machines can be very large, with mould boards of 1. 200 to 4. 000 m in width $\times$600 mm to 1. 200 m in height and a depth of cut up to 400 mm. Most bulldozers and angledozers are mounted on crawler tracks, although small bulldozers with a wheeled base are available. The control of the mould board is hydraulic, as shown in Fig. 1. 2. 1. In common with other tracked machines one of the disadvantages of this arrangement is the need for a special transporting vehicle such as a low loader to move the equipment between sites.

Before any earth-moving work is started a drawing should be produced indicating the areas and volumes of cut and fill required to enable a programme to be prepared to reduce machine movements to a minimum. When large quantities of earth have to be moved on a cut and fill basis to form a predetermined level or gradient it is good practice to draw up a mass haul diagram indicating the volumes of earth to be moved, the direction of movement, and the need to import more spoil or alternatively remove the surplus spoil from site (see Fig. 1. 2. 2 for a typical example).

SCRAPERS

This piece of plant consists of a power unit and a scraper bowl, and is used to excavate and transport soil where surface stripping, site levelling and cut and fill activities are planned. They are particularly appropriate where large volumes are encountered over a wide area, typical of civil engineering projects such as airfields and highways. These machines are capable of producing a very smooth and accurate formation level, and come in three basic types:

- crawler-drawn scraper;

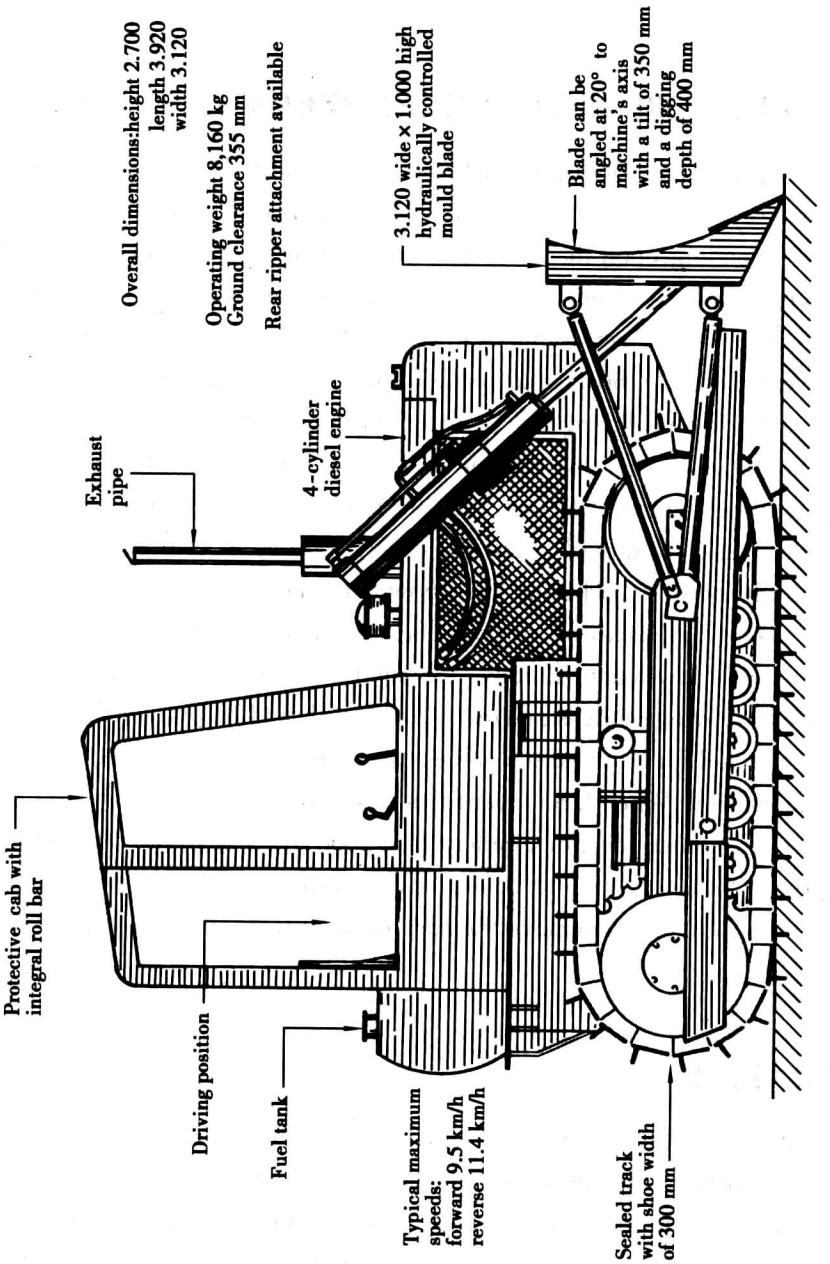
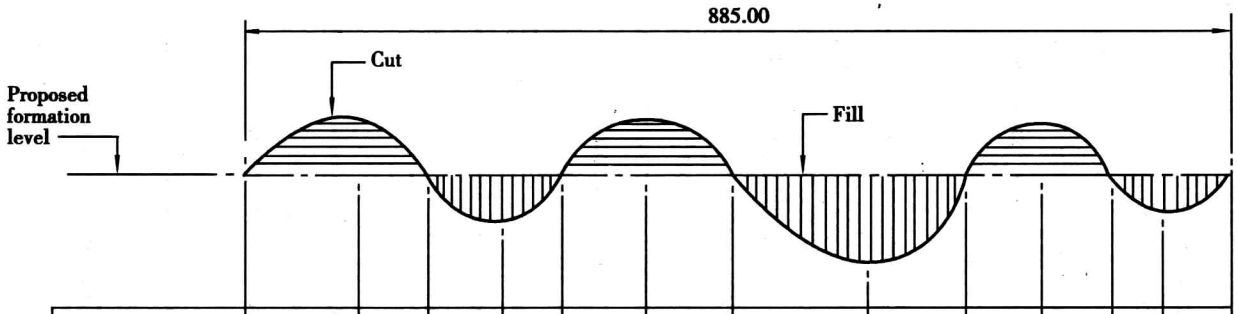


Fig. 1.2.1 Typical tractor-powered bulldozer details



Distance (m)	103	62	67	50	75	77	120	86	71	63	45	66
Volume (m^3)	7,012	3,314	3,615	3,216	4,435	4,578	9,315	5,622	4,336	3,282	2,077	3,670
Cut (m^3)	10,326				9,013				7,618			
Fill (m^3)			6,831				14,937				5,747	
Borrow (m^3)											558	
Remove (m^3)												
Haul (m^3)	6,831 → 3,495 →				9,013 →			← 2,429	5,189 →			

Fig. 1.2.2 Typical mass haul diagram

- two-axle scraper;
- three-axle scraper.

The design and basic operation of the scraper bowl is similar in all three types. It consists of a shaped bowl with a cutting edge that can be lowered to cut the top surface of the soil up to a depth of 300 mm. As the bowl moves forward the loosened earth is forced into the container, and when full the cutting edge is raised to seal the bowl. To ensure that a full load is obtained, many contractors use a bulldozer to act as a pusher over the last few metres of scrape. The bowl is emptied by raising the front apron and ejecting the collected spoil or, on some models, by raising the rear portion and spreading the collected spoil as the machine moves forwards.

The **crawler-drawn scraper** consists of a four-wheeled scraper bowl towed behind a crawler power unit. The speed of operation is governed by the speed of the towing vehicle, which does not normally exceed 8 km/h when hauling and 3 km/h when scraping. For this reason this type of scraper should be used only on small hauls of up to 300. 000 m. The **two-axle** scraper which has a two-wheeled bowl pulled by a two-wheeled power unit, has advantages over its four-wheeled power unit or three-axle counterpart in that it is more manoeuvrable, offers less rolling resistance, and has better traction because the engine is mounted closer to the driving wheels. The **three-axle scraper**, however, can use its top speed more frequently, is generally easier to control, and the power unit can be used for other activities, which is not possible with most two-axle scraper power units. Typical examples are shown in Fig. 1. 2. 3. Scraper bowl heaped capacities of the machines described above range from 5 to 50 m^3.

To achieve maximum output and efficiency of scrapers the following should be considered:

- When working in hard ground the surface should be pre-broken by a ripper or scarifier, and assistance in cutting should be given by a pushing vehicle. Usually one bulldozer acting as a pusher can assist three scrapers if the cycle of scrape, haul, deposit and return is correctly balanced.
- Where possible, the cutting operation should take place downhill to take full advantage of the weight of the unit.
- Haul roads should be kept smooth to enable the machine to obtain maximum speeds.
- Recommended tyre pressures should be maintained, otherwise extra resistance to forward movement will be encountered.