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BEDDING AND SIDEFILL MATERIALS FOR BURIED PIPELINES

FOREWORD

This Information and Guidance Note has been prepared by WRc plc under the direction of the Water Industry Engineering and Operations Committee and with the help of representatives of the UK Water Industry and pipe manufacturers. The original version of this document was published as Supplement No. 125 to the National Water Council Bulletin on 11 April 1980 and successive editions were issued in December 1987 and November 1989.

A continuing problem has been the relationship of this IGN with works specifications such as the 'Civil Engineering Specification for the Water Industry' and 'Sewers for Adoption', or Standards such as BS 8005: Part 1. Those documents need to call up a definitive specification for bedding and sidefill materials yet, by definition, an IGN is advisory in nature. It has, therefore, been decided to abstract the 'specification' element of the IGN and to publish it as a Water Industry Specification (WIS) in its own right (WIS No. 4-08-02).

The other significant change in this issue concerns basic terminology. The terms 'imported granular' and 'selected as-dug' have sometimes caused confusion and so have been replaced by 'processed granular' and 'as-dug' respectively. This is to reflect the fact that, in order to comply with a British Standard or equivalent specification, granular material is likely to require a measure of processing, for example crushing and screening, while as-dug material (whether on the site of the works or not) by definition, is not processed. The new WIS No. 4-08-02 gives specified requirements for both types of bedding and sidefill material.

Information contained in this IGN is given in good faith but the Foundation for Water Research, the Water Services Association and WRc plc can accept no responsibility for actions taken by others as a result.

CONTENTS

1. INTRODUCTION

This information note provides guidance on the selection and use of materials suitable for providing structural support to buried pipelines. Materials which fulfil this role are termed bedding and sidefill materials. This note deals both with granular materials graded in accordance with a particular specification, brought to the site for those purposes and excavated materials which have been selected as suitable. These are termed 'processed granular' materials and 'as-dug' materials respectively. The guidance given below covers pressure and non-pressure pipelines, either sewers or water mains. All such pipelines require adequate structural support to ensure their long term performance. Figure 1 shows a typical trench configuration and illustrates some of the terminology adopted in this information note. An appropriate specification for bedding and sidefill material is given in Water Industry Specification No. 4-08-02.

The use of foamed concrete or normal concrete bedding and sidefill materials is not covered by this IGN or WIS No. 4-08-02. These materials require special consideration in use.

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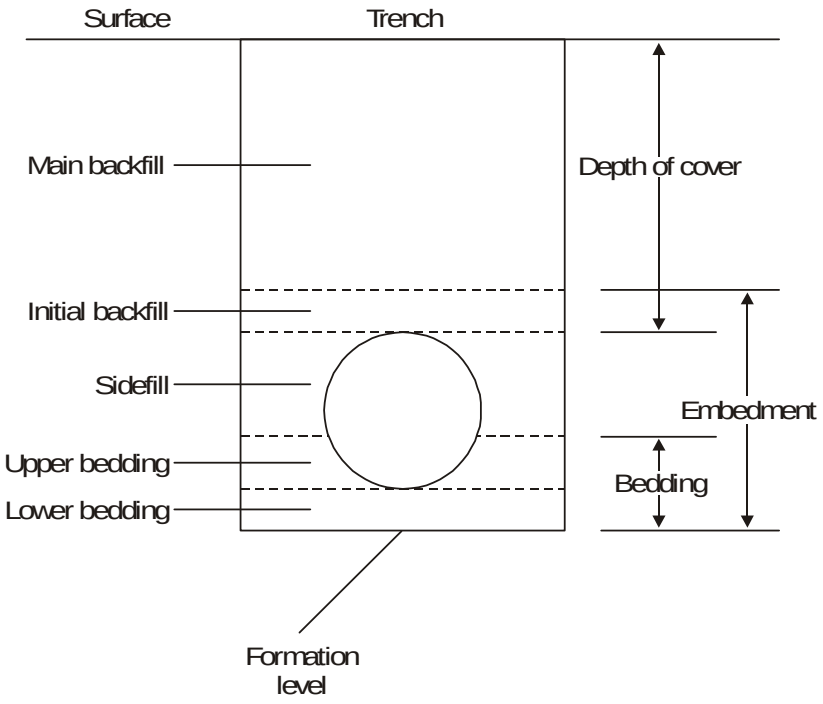

Figure 1 – Typical trench configurations

2. DEFINITIONS

As-dug material: Excavated material which is suitable for use as bedding and sidefill without processing.

Embedment: The filling above the formation level around the pipe extending to the bottom of the main backfill. Embedment includes bedding, sidefill and initial backfill.

Flexible pipe: A pipe whose load carrying capacity is limited by deformation under load to the ultimate design criteria without breaking or overstressing.

Processed granular material: Granular material processed to meet the requirements of specified criteria.

Rigid pipe: A pipe whose load-carrying capacity is limited by breaking or overstressing, without significant deformation of its cross section.

Semi-rigid pipes: A pipe which may be considered as either rigid or flexible according to the relationship between its stiffness and the applied load.

3. BEDDING AND SIDEFILL PROPERTIES

Pipes used in the construction of buried pipelines can be divided into two main categories; rigid and flexible. A rigid pipe has inherent load carrying capability which the bedding and sidefill serve to enhance. Vitrified clay and concrete pipes are typical of the products that fall into this category. A flexible pipe functions by transferring part of the load into the sidefill, by deforming to some degree. Typical flexible pipe materials are unplasticised polyvinylchloride (PVC-U) and polyethylene (PE). Some pipe materials will fall into either category depending on design circumstances and are termed semi-rigid.

The pipe installation should be designed so that the pipeline will not suffer structural failure due to the loads acting on it. The design should take account of the load applied to the pipe by the ground above it including traffic and other loads transmitted from the surface. The design should also take account of the standard of workmanship anticipated during laying. Bedding and sidefill materials must therefore have properties which match the design assumptions.

Another property which should be considered is the permeability of the bedding and sidefill materials. The

passage of water into or along a permeable conduit created by bedding materials can give rise to problems of stability (see Section 4). Problems can also arise with the transfer of polluted water or gases from contaminated land.

The bedding and sidefill materials, used to support a pipe, may be processed granular or as-dug material. The installation design may require the pipe to be fully surrounded with one of these materials. Alternatively, both may be employed, for example, a bed of processed granular material may be placed below the pipe, with as-dug material used as sidefill.

For rigid pipe, the bedding material transfers the support reaction from the formation to the pipeline. If this reaction is well distributed, the load carrying capacity of the pipes is increased. The greater the arc of support, the greater the pipe's load-carrying capacity becomes. For design purposes this effect is reflected in the bedding factor.

Flexible pipes are assisted in the carrying of vertically imposed loads by the support given by the bedding and sidefill materials, which as the pipe deflects transfer the loads from the backfill and ground surface to the native soil adjacent to the pipe. Whilst achieving this, the bedding and sidefill materials must also control the deformation of the pipe under load to acceptable levels.

Ideal bedding and sidefill material should have the following general properties.

(a) it should be easy to scrape or shovel to form a bed on which to lay a pipe, and also be easy to distribute uniformly beneath the haunches of a pipe by tamping;

(b) it should require little or no compactive effort;

(c) the largest particle size should not be excessive in relation to the pipeline diameter otherwise impact damage and concentrated point loading can occur;

(d) it should not contain particles with sharp edges when used with those pipes or pipe coatings that are susceptible to damage;

(e) the grading should be such that water passing through will not encourage fine materials to be carried away and thus reduce the support for the pipeline;

(f) it should not break up when wetted or compacted;

(g) it should not cause corrosion or degradation of the pipes, fittings, coatings and jointing materials with which it is in contact;

(h) it should be sufficiently stable, when laid and compacted, to support the pipeline in the correct position both during and after laying;

(i) it should be chemically durable and not react with, the soil, groundwater, pipe or coating.

4. SELECTION OF SUITABLE BEDDING AND SIDEFILL MATERIALS

It will seldom be possible to select a material that will have all the ideal properties described in Section 3.

Consequently when selecting a suitable material consideration must be given to:

(a) where and how the material is to be used;

(b) the chosen installation design, contract specification and expected level of site supervision;

(c) the expected ground conditions;

(d) the acceptable maximum particle size and shape;

(e) the chemical properties;

(f) the maintenance of correct alignment during installation;

(g) the capability of being compacted within the available trench width to the required density with a degree of compactive effort that will not cause the pipe to be overstrained or suffer impact damage;

(h) the selection of a compatible pipe coating or, where this is not possible, the use of a protective shield.

Movement of water can cause migration of fine soil particles through the interstices of the bedding and sidefill materials. This removal of material from the sides and bottom of the trench can cause instability.

The gradings of bedding and sidefill materials may be selected so as to prevent this migration whilst endeavouring to ensure that the other required properties are not impaired, such as compactibility. Alternatively, migration may be minimised by surrounding the bedding and sidefill materials with an appropriate geotextile, or by inhibiting the flow of water along the trench by the use of puddled clay stanks.

Aggregates conforming to BS 882, air-cooled blast furnace slag conforming to BS 1047, or lightweight aggregates conforming to BS 3797 are suitable as processed bedding and sidefill materials. Air-cooled blast furnace slag and lightweight aggregates are currently not recommended for use with ductile iron or steel pipelines due to the potential risk of corrosion. For cementitious pipes the sulphate content of material, particularly industrial by-products, should not be such as to create an unacceptable exposure condition. Further guidance may be found in BRE Digest 363.

Good alignment of heavy pipes will be more easily achieved by the selection of angular bedding materials as these will help ensure stability during installation. Crushed rock aggregates to BS 882 are particularly suitable. Air-cooled blast furnace slag to BS 1047, lightweight aggregates to BS 3797 or other materials may be used if they show a similar degree of angularity. Other stable materials, for example all-in ballast, because of their particle size distribution may also be suitable.

The compactive effort required to achieve the desired degree of compaction will be principally influenced by angularity in coarser materials such as gravels and by moisture content in finer materials such as sands. Angular materials will require greater compactive effort.

As-dug materials will often be derived from the soil excavated from the pipe trench. **Material excavated from land contaminated with domestic, building or industrial waste should not be used as bedding and sidefill materials**. As-dug materials should be readily compactible and free from organic matter and combustible materials. Soil should not be used in a frozen state.

Where as-dug material is to be used as a bedding material the maximum particle sizes given in Tables A.1 or A.2 shall still apply.

Where as-dug material is to be used only as a sidefill material, maximum particle sizes larger than those specified in Tables A.1 and A.2 can often be used without problems. The maximum size acceptable should be decided by consideration of the following factors:

(a) the level of site supervision;

(b) possible damage to the pipes or their coatings;

(c) the effect on the compactibility of the sidefill material;

(d) the trench width.

Where the structural performance of the pipeline does not depend on the sidefill, (e.g. for some rigid pipe installations) sidefill may contain stones up to 37.5mm and clay lumps up to 75mm for any pipe diameter. For rigid pipes larger than DN 500, stone sizes up to 10% of the pipe diameter will normally be acceptable.

As-dug non-cohesive bedding and sidefill materials on which the structural performance of the pipeline does depend should be evaluated using the Compaction Fraction Test, detailed in WIS No. 4-08-02. Materials are suitable if the values obtained do not exceed those given in Appendix A, Tables A.1 and A.2 for rigid and flexible pipes respectively.

Selected as-dug cohesive bedding and sidefill materials should be evaluated by referring to site investigation data and monitoring the excavated soil. Appendix A, Table A.3 provides typical modulus values for materials for use in flexible pipe design.

For pipes laid under highways, reference should be made to the Specification For The Reinstatement Of Openings In Highways (HAUC Specification). In particular, this gives requirements that clays having a Liquid Limit (LL) exceeding 90 or a Plasticity Index (PI) exceeding 65 when tested in accordance with BS 1377: Part 2, Methods 4 and 5.4 respectively are not to be used, and stone sizes in excess of 37.5mm are unacceptable.

5. REFERENCES

This guidance note makes reference to the latest edition of the following publications (except where otherwise stated), including all addenda and revisions, which should also be consulted.

British Standards

BS 882	Specification for aggregates from natural sources for concrete.
BS 1047	Specification for air-cooled blast furnace slag aggregate for use in construction.
BS 1377	Methods of test for soils for civil

engineering purposes

BS 3797 Specification for lightweight aggregates for masonry units and structural concrete.

BS 8005 Part 1: Guide to new sewerage construction.

Water Industry Specifications/ Information and Guidance Notes

WIS No. 4-08-02 Specification for bedding and sidefill materials for buried pipelines.

IGN No. 4-11-02 Revised bedding factors for vitrified clay drains and sewers.

Other

BRE Digest 363. Sulphate and acid resistance of concrete in the ground. 1991.

HMSO. Specification for the Reinstatement of Openings in Highways. 1992.

TRANSPORT AND ROAD RESEARCH LABORATORY. Simplified tables of external loads on buried pipelines. 1986.

WAA. Sewers for Adoption. Edition 3, 1989.

WATER SERVICES ASSOCIATION. Civil Engineering Specification for the Water Industry. 4th Edition. 1993.

WRc. Report ER201E. Guide to the Water Industry for the structural design of underground non-pressure uPVC pipelines. 1986.

APPENDIX A – TABLES OF SUITABLE BEDDING AND SIDEFILL MATERIALS

Table A.1 – Processed granular bedding materials for rigid pipes

Pipe nominal size (DN)	Nominal maximum particle size (mm) See note (c)	Class of bedding See note (d)	Maximum CF value for acceptability See note (b)	Materials specified in British Standards See note (a)
100	10	S B F	0.15 0.30 0.15	10mm nominal single-size
		N	0.30	Coarse, medium or fine sand
Over 100 to 150	15	S B F	0.15 0.30 0.15	10 or 14mm nominal single-size or 14mm to 5mm graded
		N	0.30	Coarse, medium or fine sand
Over 150 to 300	20	S B F	0.15 0.30 0.15	10, 14 or 20mm nominal single-size or 14mm to 5mm graded or 20mm to 5mm graded
		N	0.30	All-in aggregate or coarse, medium or fine sand
Over 300 to 550	20	S B F	0.15 0.30 0.15	14 or 20mm nominal single-size or 14 to 5mm graded or 20 to 5mm graded or 20 to 5mm graded
		N	0.30	All-in aggregate or coarse, medium or fine sand
Over 550	40	S B F	0.15 0.30 0.15	14, 20 or 40mm nominal single-size crushed rock or 14mm to 5mm graded or 20mm to 5mm graded or 40mm to 5mm graded
		N	0.30	All-in aggregate or coarse, medium or fine sand

Notes:

(a) Processed granular materials to include aggregates to BS 882, air-cooled blastfurnace slag to BS 1047 and lightweight aggregates to BS 3797.

(b) Compaction Fraction value (CF), see WIS No. 4-08-02.

(c) The nominal maximum particle sizes apply both to processed and as-dug materials (see Section 4). Materials specified in the British Standards listed in note (a) allow an acceptable percentage of larger particles to be present provided that 100% passes the next larger sieve size in the range of sieves used in these standards.

(d) Bedding classes are defined in:-
BS 8005: Part 1
IGN No. 4-11-02
TRRL – Simplified Tables of External Loads on Buried Pipelines.

(e) The sulphate content of bedding and sidefill materials for use with cementitious pipe should not be greater than 0.3% as sulphur trioxide.

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Table A.2 - Processed granular bedding and sidefill materials for flexible pipes

Pipe nominal bore (mm) See note (d)	Nominal maximum particle size (mm)	Maximum CF value for acceptability See note (b)		Materials specified in British Standards See note (a)
		Non-pressure pipe	Pressure pipe	
100	10	0.15	0.30	10mm nominal single-size
Over 100 to 150	15	0.15	0.30	10 or 14mm nominal single-size or 14mm to 5mm graded
Over 150 to 300	20	0.15	0.30	10, 14 or 20mm nominal single-size or 14mm to 5mrn graded or 20mm to 5mm graded
Over 300 to 550	20	0.15	0.30	14 or 20mm nominal single-size or 14mm to 5mm graded or 20mm to 5mm graded
Over 550	40	0.15	0.30	14, 20 or 40mm single-size or 14mm to 5mm graded or 20mm to 5mm graded or 40mm to 5mm graded

Notes:
(a) Processed granular materials to include aggregates to BS 882, air-cooled blastfurnace slag to BS 1047 and lightweight aggregates to BS 3797.
(b) Compaction Fraction value (CF), see WIS No. 4-08-02.
(c) For the purpose of this table, PE pipes of 630mm OD can be regarded as having nominal bores of over 550mm, irrespective of wall thickness.
(d) Nominal bore is used in preference to DN because of the different nominal size classifications for flexible pipes.
(e) For PE80 and PE100 polyethylene pipe complying with current relevant Water Industry Specifications, the maximum sidefill particle size may be increased to 10% of the pipe nominal size.
(f) For E´ values for processed granular materials reference should be made to Table A.3 where specific site tests have not been performed.
(g) For ferrous and cementitious pipeline materials, the sulphate content of bedding and sidefill materials should not be greater than 0.3% as sulphur trioxide.

Table A.3 – Typical modulus values for processed and as-dug bedding and sidefill materials for use in flexible pipeline design

Material		Modulus of Soil Reaction E' (MN/m^2) See note (a2)				
Description	Casagrande symbol See note (d)	Degree of compaction				
		Uncompacted See note (a1)	80% Modified Proctor	85% Modified Proctor	90% Modified Proctor	95% Modified Proctor See note (b)
Gravel single-sized	GPu	5	7	7	10	14
Gravel graded	GW	3	5	7	10	20
Sand and coarse grained soil with less than 12% fines	GP SW SP	1	3	5	7	14
Coarse grained soil with more than 12% fines	GM GC SM	*	1	3	5	10
Fine grained soil with medium to no plasticity and containing more than 25% coarse grained particles (LL<50%) See note (e)	CL, ML mixtures ML/CL and ML/MH	*	1	3	5	10
Fine grained soil with medium to no plasticity and containing less than 25% coarse grained particles (LL<50%) See note (f)	CL, ML mixtures ML/CL and ML/MH	*	*	1	3	7

Notes:

* No reliable modulus values for these materials.

(a1) For any situation where bedding and sidefill trench material must be placed and compacted within temporary trench supports, the value chosen for E´ should be that associated with uncompacted material.

(a2) Refer to ER201E for the meaning and use of modulus of soil reaction, E´.

(b) BS 1377, 'Determination of the dry density/moisture content relationship (4.5kg rammer method)', is used to determine the Modified Proctor Density.

(c) Semi-rigid pipes can be designed as either flexible or rigid.

(d) GPu - Poorly graded uniform gravel
GW - Well graded gravel
GP - Poorly graded gravel
SW - Well graded sand
SP - Poorly graded sand
GM - Very silty sand
GC - Very clayey gravel
SM - Very silty sand
CL - Clays with low plasticity
ML - Silts with low plasticity
CI - Clays with intermediate plasticity
MI - Silts with intermediate plasticity
CL-ML - Mixtures of ML and CL
CI-MI - Mixtures of MI and CI

(e) Clays and silts, with a Liquid Limit (LL) less than 50% and an appreciable fraction passing the 75μm BS test sieve, with more than 25% coarse grained particles.

(f) As note (e) with less than 25% coarse grained particles.