

PETRONAS TECHNICAL STANDARDS

DESIGN AND ENGINEERING PRACTICE

TECHNICAL SPECIFICATION

REINFORCED CONCRETE FOUNDATION AND STRUCTURE

PTS 34.19.20.31
NOVEMBER 2009



© 2010 PETROLIAM NASIONAL BERHAD (PETRONAS)

All rights reserved. No part of this document may be reproduced, stored in a retrieval system or transmitted in any form or by any means (electronic, mechanical, photocopying, recording or otherwise) without the permission of the copyright owner.



Documents

Document Sharing Hub

PTS Circular 2009 - 1	PETRONAS 
PTS No:	PTS 34.19.20.31
Publication Title:	Reinforced Concrete Foundation and Structures
Base PTS Version:	Release 13

This revision of PTS **34.19.20.31 – Reinforced Concrete Foundation and Structures (November 2009, Revision 1)** has been updated incorporating PETRONAS Lessons Learnt, Best Practice and information issued by relevant industry code and standards. All updates in the document are highlighted in *italic* font.

The previous version of this PTS (**Revision 13, December 1998**) will be removed from PTS binder/ e-repository from herein onwards.

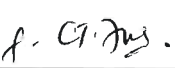
The custodian of this PTS is:

Name : Ir. M Nazri bin Mustafa

Tel. No : 03 – 2783 6413

Please direct any questions regarding this PTS to the above-named.

Document Approval

	Name	Designation	Date	Signature
Prepared	Sek Chin Yong	Civil Engineer	20.11.2009	
Reviewed	Jamil bin Jamaluddin	Senior Civil Engineer	20.11.2009	
Approved	Ir. Mohd Nazri bin Mustafa	TP Principal	20.11.2009	
Verified	Hashim bin Zainal Abidin	Technical Manager, (CSP), GTS	20/11/09	
Endorsed	Pau Kiew Huai	General Manager, Engineering - GTS	24.11.09	

Revision History

Date	Version	Description of Updates	Author

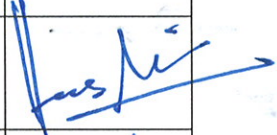
Correction to PTS 34.19.20.31 - Reinforced Concrete Foundation and Structures (updated November 2009)

This is to notify that the following items have been revised with immediate effect for PTS 34.19.20.31 - Reinforced Concrete Foundation and Structures (updated November 2009) :

1. Section 1.5 and 1.6 have been deleted from the content
2. Section 5. Formwork – the content has been revised to match the requirements from BS 8110.
3. Appendix 1 – Aggressivity of Environment and Recommendation for Mix Design – Table 1 & Table 2 have been revised.

Revised contents are shown in the following page. The revised contents have been incorporated into the PTS.

Document Approval

	Name	Designation	Date	Signature
Prepared	Jamil b. Jamaluddin	Civil Engineer	08/09/2010	
Review / Approved	Ir Mohd Nazri b. Mustafa	Principal Civil Engineer	08.09.2010	
Verified	Hashim b. Zainal Abidin	Technical Manager, CSP, Engineering, GTS	15/09/10	
Endorsed	Pau Kiew Huai	General Manager, GTS	15.9.10	

PREFACE

PETRONAS Technical Standards (PTS) publications reflect the views, at the time of publication, of PETRONAS OPU/Divisions.

They are based on the experience acquired during the involvement with the design, construction, operation and maintenance of processing units and facilities. Where appropriate they are based on, or reference is made to, national and international standards and codes of practice.

The objective is to set the recommended standard for good technical practice to be applied by PETRONAS' OPU/Divisions in oil and gas production facilities, refineries, gas processing plants, chemical plants, marketing facilities or any other such facility, and thereby to achieve maximum technical and economic benefit from standardisation.

The information set forth in these publications is provided to users for their consideration and decision to implement. This is of particular importance where PTS may not cover every requirement or diversity of condition at each locality. The system of PTS is expected to be sufficiently flexible to allow individual operating units to adapt the information set forth in PTS to their own environment and requirements.

When Contractors or Manufacturers/Suppliers use PTS they shall be solely responsible for the quality of work and the attainment of the required design and engineering standards. In particular, for those requirements not specifically covered, the Principal will expect them to follow those design and engineering practices which will achieve the same level of integrity as reflected in the PTS. If in doubt, the Contractor or Manufacturer/Supplier shall, without detracting from his own responsibility, consult the Principal or its technical advisor.

The right to use PTS rests with three categories of users :

- 1) PETRONAS and its affiliates.
- 2) Other parties who are authorised to use PTS subject to appropriate contractual arrangements.
- 3) Contractors/subcontractors and Manufacturers/Suppliers under a contract with users referred to under 1) and 2) which requires that tenders for projects, materials supplied or - generally - work performed on behalf of the said users comply with the relevant standards.

Subject to any particular terms and conditions as may be set forth in specific agreements with users, PETRONAS disclaims any liability of whatsoever nature for any damage (including injury or death) suffered by any company or person whomsoever as a result of or in connection with the use, application or implementation of any PTS, combination of PTS or any part thereof. The benefit of this disclaimer shall inure in all respects to PETRONAS and/or any company affiliated to PETRONAS that may issue PTS or require the use of PTS.

Without prejudice to any specific terms in respect of confidentiality under relevant contractual arrangements, PTS shall not, without the prior written consent of PETRONAS, be disclosed by users to any company or person whomsoever and the PTS shall be used exclusively for the purpose they have been provided to the user. They shall be returned after use, including any copies which shall only be made by users with the express prior written consent of PETRONAS. The copyright of PTS vests in PETRONAS. Users shall arrange for PTS to be held in safe custody and PETRONAS may at any time require information satisfactory to PETRONAS in order to ascertain how users implement this requirement.

TABLE OF CONTENTS

1.	INTRODUCTION
1.1	SCOPE
1.2	DISTRIBUTION, INTENDED USE AND REGULATORY CONSIDERATIONS
1.3	DEFINITIONS
1.4	CROSS-REFERENCES
2.	PREPARATORY WORK
2.1	SETTING OUT
2.2	PILING AND SOIL IMPROVEMENT
2.3	SITE PREPARATION, EXCAVATION, BACKFILL AND TEMPORARY DRAINAGE
2.4	BLINDING CONCRETE OR BUILDING PAPER
3.	DESIGN OF FOUNDATIONS AND STRUCTURES
3.1	BASIS OF DESIGN
3.2	DESIGN DETAILS
3.3	SPECIAL FOUNDATIONS AND STRUCTURES
4.	MATERIALS
4.1	CEMENT
4.2	AGGREGATES
4.3	REINFORCING MATERIAL
4.4	WATER
4.5	CONCRETE MIXES
4.6	EXPOSURE CONDITIONS
5.	FORM WORK
5.1	GENERAL
5.2	REMOVAL
6.	REINFORCEMENT
6.1	CUTTING, BENDING AND WELDING
6.2	PLACING
7.	CONCRETE MEASURING, MIXING, PRODUCTION, TRANSPORTING AND WEATHER PROVISIONS
7.1	MEASURING , MIXING, PRODUCTION AND TRANSPORTING
7.2	ADMIXTURES AND ADDITIONS
7.3	EXTREME WEATHER PROVISIONS
7.4	HEAT OF HYDRATION
8	CONCRETE PLACING
8.1	GENERAL
8.2	FINISHING AND REPAIR
9.	CURING OF CONCRETE
10.	GROUTING
10.1	TYPES OF GROUT
10.2	SURFACE PREPARATION
10.3	APPLICATION
11.	QUALITY PLAN
11.1	GENERAL
11.2	PRODUCTION/EXECUTION QUALITY PLAN
12.	CHEMICAL-RESISTANT CONSTRUCTIONS
13.	ANCHOR BOLTS, PIPE SLEEVES, BOLTS, ETC.

- 14. **MAINTENANCE**
- 15. **REFERENCES**
- 16. **BIBLIOGRAPHY**

APPENDICES

- APPENDIX 1 AGGRESSIVITY OF THE ENVIRONMENT AND RECOMMENDATIONS
 FOR MIX DESIGN
- APPENDIX 2 INSPECTION AND REPAIR
- APPENDIX 3 TESTS

1. INTRODUCTION

1.1 SCOPE

This PTS specifies requirements and give recommendations for the design, engineering and construction of reinforced concrete foundations and structures. It shall be used in conjunction with PTS 34.00.01.30.

This PTS is a revision of the PTS of the same number dated December 1998

1.2 DISTRIBUTION, INTENDED USE AND REGULATORY CONSIDERATIONS

Unless otherwise authorised by PETRONAS, the distribution of this document is confined to companies forming part of PETRONAS or managed by a Group Company, and to Contractors nominated by them.

This PTS is intended for use in oil refineries, chemical plants, gas plants, onshore exploration and production facilities and supply/marketing installations.

If national and/or local regulations exist in which some of the requirements may be more stringent than in this PTS, the Contractor shall determine by careful scrutiny which of the requirements are the more stringent and which combination of requirements will be acceptable as regards safety, environmental, economic and legal aspects. In all cases the Contractor shall inform the Principal of any deviation from the requirements of this PTS which is considered to be necessary in order to comply with national and/or local regulations. The Principal may then negotiate with the Authorities concerned with the object of obtaining agreement to follow this PTS as closely as possible.

1.3 DEFINITIONS

The **Contractor** is the party which carries out all or part of the design, engineering, procurement, construction, commissioning or management of a project or operation of a facility. The Principal may undertake all or part of the duties of the Contractor.

The **Manufacturer/Supplier** is the party which manufactures or supplies equipment and services to perform the duties specified by the Contractor.

The **Principal** is the party which initiates the project and ultimately pays for its design and construction. The Principal will generally specify the technical requirements. The Principal may also include an agent or consultant authorised to act for, and on behalf of, the Principal.

The word **shall** indicates a requirement.

The word **should** indicates a recommendation.

1.4 CROSS-REFERENCES

Where cross-references to other parts of this PTS are made, the referenced section number is shown in brackets. Other documents references in this PTS are listed in (15).

2. PREPARATORY WORK

2.1 SETTING OUT

All work shall be set out accurately from datum and benchmarks. During execution the correct position, level and alignment of all parts of the work shall be ensured at all times.

Setting out shall meet the requirements of BS 8110-1, clause 6.2.8 (see also references to BS 5964:Part 3:1996 or ISO 4463-3:1995), with the following additions:

	Item	Distance	Permitted tolerance
1	Variation from the plumb	In 2.50 m	+/- 5 mm
2	In the lines and surfaces of columns, piers, walls and arises	In any story or 5.00 m max. and in 25.00 m	+/- 5 mm +/- 50 mm
3	Variation from the level or from the grades indicated on the drawings. Note: Sufficient slope shall cover the tolerance to avoid water ponding.	In 3.00 m in any bay or 6.00 m max.	+/-5mm +/-10mm
4	Variation in the thickness of slabs and walls		+/- 6 mm
5	Misplacement or eccentricity		+/- 10 mm

2.2 PILING AND SOIL IMPROVEMENT

Piling and soil improvement, if required, shall be in accordance with PTS 34.11.00.12

2.3 SITE PREPARATION, EXCAVATION, BACKFILL AND TEMPORARY DRAINAGE

Site preparation, excavation, back fill and temporary drainage shall be in accordance with PTS 34.11.00.11

2.4 BLINDING CONCRETE OR BUILDING PAPER

2.4.1 Blinding concrete

A layer of blinding concrete of 50 mm minimum thickness shall be placed under foundations. The blinding layer shall be laid immediately after excavation, draining and compacting of the bed area, in order to avoid disturbance of soil by rain or ground water.

2.4.2 Building paper

Underneath concrete paving slabs, building paper may be used directly on the soil, instead of blinding concrete. The building paper shall comply with BS 1521 or be heavy-duty polyethylene film of at least 0.15 mm thickness, in the longest length and widest width available. The overlap shall be not less than 150 mm at all joints and intersections.

3. DESIGN OF FOUNDATIONS AND STRUCTURES

3.1 BASIS OF DESIGN

3.1.1 Design data

For loading data, reference is made to PTS 34.00.01.30

3.1.2 Design and calculations

The design and calculations of reinforced concrete structures shall be based on BS 8110 with exception of crack width control. For this subject the CEB-FIP Model Code 1990 shall be used. Reference is also made to section 3.2.4 in this respect.

The application of pre-stressed concrete may be used for the following members only:

- a) walls for LNG/LPG storage tanks;
- b) bridge and culvert decks in roads, main beams and/or walls to be cast-in-place;
- c) structures for buildings in the administration area (outside the 200 m zone), refer PTS 34.17.00.32;
- d) piles;
- e) other items outside the process plant area, where the risk of fire is limited.

3.2 DESIGN DETAILS

3.2.1 Constructional and movement joints

Where required, constructional and/or movement joints shall be provided in concrete structures.

3.2.2 Concrete cover

The minimum concrete cover on the outer reinforcement shall be as follows:

	Minimum cover
a) Cast-in-place concrete (nonpre-stressed)	
- Cast against and permanently exposed to earth	75 mm
- Exposed to earth, weather or water	50 mm
- Not exposed to weather or not in contact with the ground: slabs, walls, beams, girders, columns	40 mm
- In contact with or above sea water underside and sides of slabs top side of slab beams	75 mm 50 mm 75 mm
b) Pre-cast concrete (manufactured under plant conditions)	
- Exposed to earth, weather or water wall panels other members	40 mm 50 mm
- Not exposed to weather or not in contact with the ground slabs, walls, joints beams, girders, columns	30 mm 40 mm
- In contact with or above sea water underside and sides of slab top side of slab beams	75 mm 50 mm 75 mm
c) Pre-stressed concrete members	
- Cast against and permanently exposed to earth	75 mm
- Exposed to earth, weather or water horizontal surfaces non-horizontal surfaces	75 mm 50 mm
- Not exposed to weather or in contact with the ground	40 mm
- In contact with or above sea water underside and sides of slab top side of slab beams	75 mm 50 mm 75 mm

3.2.3 Spacing of bars

The minimum distance between individual bars shall be the largest of:

- the maximum size of coarse aggregate + 5 mm;
- the diameter of the bar;
- 50 mm.

The centre-to-centre distance of individual bars shall be as follows:

not more than 150 mm	-	for main bars in beams where bending moments are maximum
not more than 250 mm	-	for main bars in slabs where bending moments are maximum
	-	for bars perpendicular to main bars in slabs
	-	for distribution bars in slabs
	-	for bars in walls
	-	for mild steel stirrups in beams
not more than 300 mm	-	for longitudinal bars in columns
	-	for horizontal side bars in beams
	-	for high-yield stirrups in beams
not more than 400 mm	-	for any other bars not mentioned previously, provided the cross bars are spaced not more than 250 mm

In walls and floors with a thickness of 250 mm or more, reinforcing bars shall be placed on both sides, over the full section.

In footings and foundation slabs/blocks with a thickness of 250 mm or more, reinforcing bars shall be placed on both top and bottom, over the full section.

The space between the bars shall not exceed 250 mm. In addition, horizontal side reinforcement shall be placed at minimum distances of 400 mm.

3.2.4 Crack width control

Crack width control shall satisfy the requirements of the CEB-FIP Model Code 1990.

3.2.5 Shrinkage reinforcement

When walls or slabs are not cast monolithically (restraint condition), attention shall be paid to reinforcement required due to differential shrinkage.

Shrinkage reinforcement shall be calculated and applied where necessary.

3.3 SPECIAL FOUNDATIONS AND STRUCTURES

3.3.1 Foundations for small equipment

Foundations for small pumps, staircases, etc. may be placed on reinforced concrete slabs or yard paving, provided that they are properly connected to the slabs or paving and that cable trench locations are fixed. If required, slabs or paving shall be strengthened locally.

3.3.2 Liquid-retaining structures

In addition to all other requirements for the design of structures, special precautions shall be taken regarding the liquid tightness of liquid-retaining structures. See BS 8007: 1987. All liquid retaining structures shall be water tested under atmospheric pressure conditions, unless otherwise stated.

3.3.3 Reinforced concrete stacks

Reference is made to PTS 34.24.27.31

3.3.4 Foundations and structures subject to vibration

3.3.4.1 Design

A detailed design and vibration analysis shall be performed in accordance with PTS 34.00.01.30

3.3.4.2 Isolation of foundations

Foundations subject to vibration shall in, principle, be properly isolated from adjacent structures.

Combined foundations shall also meet the requirements of PTS 34.00.01.30

3.3.5 Foundations subject to temperature effects

Foundations and structures subject to temperature effects shall be designed for any temperature difference that may occur in parts of structural members and/or the whole structure.

For loading resulting from temperature differences, see PTS 34.00.01.30, subsection 2.10.

3.3.6 Box-outs and curbs

All holes in table tops which have equipment underneath shall be closed after installation of piping, equipment, etc. to prevent escalation of a fire which may occur under the table top because of draught through such holes.

All edges of table top slabs shall have a curb of minimum 100 mm height to prevent liquid and rainwater from being drained over the edge, except at locations of entrance such as staircases and connections to other platforms. The table top slabs shall be sloped to discharge drains or gullies provided with down spouts.

4. MATERIALS

4.1 CEMENT

4.1.1 Cement for general application

For general application, the cement to be used shall be normal Portland cement in accordance with BS 12 or ASTM C 150 or equivalent, unless otherwise specified.

4.1.2 Cement for special applications

If soil conditions, groundwater, sea water or refinery effluent water are harmful to normal Portland cement, the most appropriate of the following types of cement shall be used (see also [Appendix 1](#)):

- Blast furnace type cement shall be used.
- Portland blast-furnace cement in accordance with BS 146 or Portland cement type II in accordance with ASTM C 150.
- Sulphate-resisting Portland cement in accordance with BS 4027 or Portland cement type V in accordance with ASTM C 150.
- Portland blast-furnace cement in accordance with BS 146 or Portland cement type II in accordance with ASTM C 150.

When low heat dissipation of hydration is required:

- Portland cement type IV in accordance with ASTM C 150.

4.1.3 High-alumina cement

High-alumina cement is only allowed for non-structural applications.

4.1.4 Test certificate

A Manufacturer's test certificate, indicating the particular batch number or fabrication date, etc. shall be submitted by the Supplier before or simultaneously during the delivery of the cement.

4.1.5 Transport and Storage

The cement shall be delivered to the site in three ply bags or in bulk carriers. Bags transported by sea shall be packed in plastic. The name and brand of the manufacturer, including batch number or fabrication date shall be plainly marked on the bags.

The cement shall be stored in such a way that the date of manufacturing is clearly visible so that it is used in sequence by the date of manufacture, oldest first.

The maximum height of storage of the bags shall be 2 m with a ventilated space between the floor and lowest bags. In tropical and subtropical areas the outside of the cement storage shall be painted in a reflected white colour.

A cement storage shall be provided with the following:

- concrete floor;
- waterproof walls and roof;
- ventilation in the building to prevent condensation;
- adequate drainage system;
- air-conditioning system to control the temperature between 0 °C and < 40°C.

The bulk cement shall be stored in a silo. The silo shall comply with the following:

- in hot climates the silo shall be painted in a reflective white colour;
- in all areas the temperature shall not exceed 40°C and/or shall be maintained frost-proof.

The cement shall be suitably protected during storage to avoid deterioration in quality.

Cement which has been in storage for more than 3 months from the date of manufacture shall be tested to verify that its quality is still in accordance with the standards referred to in (5.1.1) or (5.1.2).

The presence of lumps will lead to rejection of the cement. Cement older than 6 months shall not be used.

4.2 AGGREGATES

Coarse and fine aggregates shall comply with BS 882 or ASTM C 33 or approved equivalent.

The content of acid-soluble chlorides (expressed as Cl) should not exceed 0.06% by wt of fine aggregates and 0.03% by wt of coarse aggregates.

The content of acid-soluble sulphates (expressed as calculated SO₃ equivalent) shall not exceed 0.4% by wt of fine aggregates and 0.4% by wt of coarse aggregates.

The aggregates shall be tested for possible alkali reaction or other deleterious reactivity.

At all times, the aggregates shall be free of impurities and if not, the aggregates shall be washed mechanically with water (as specified in 5.4) to remove clay, silt and fine dust.

Note: Attention is drawn to the possibility of alkali reactive aggregates. Every effort shall be made to select non-reactive aggregates and make use where possible of proven reliable sources. This also applies to aggregates with lower chloride diffusion resistance.

4.3 REINFORCING MATERIAL

In general the reinforcing material work shall be in accordance with BS 4449, BS 4483, ENV 10080, ASTM A 615 and ASTM A 617.

Reinforcing material for general concrete work shall be hot rolled high yield deformed bars.

Reinforcing material for pre-stressed concrete in cryogenic environment shall be suitable for cryogenic temperatures and in accordance with BS 5896.

4.4 WATER

Only clean, fresh water free from harmful matter shall be used. It shall not contain chlorides (Cl) in excess of 500 mg/kg nor sulphates (SO₃) in excess of 500 mg/kg.

The water shall not contain dissolved solids in excess of 2000 mg/kg.

Furthermore the water shall not contain sugars, phosphates and harmful impurities (for instance oil).

The pH of the water shall be > 5.0.

Tests shall be carried out in accordance with BS 3148 and BS 2690.

In hot and cold climates the water shall be chilled or heated water respectively in accordance with CEB-FIP Model Code 1990.

4.5 CONCRETE MIXES

The concrete mix design shall take into account the type of foundations, structures, elements etc. for which it is intended.

Special attention shall be paid to possible bleeding after placing. Trial tests, including a

bleeding test in accordance with ASTM C 232, shall be performed especially for large/thick horizontal slabs.

Special admixtures may be considered if bleeding cannot be controlled sufficiently by means of a standard mix design. In general a low slump in combination with proper grading and/or the use of an air entrainer may prevent bleeding. Reference is made to BS 5328-1, clause 7.2.

The required concrete mixes shall be designed in accordance with CEB-FIP Model Code or BS 5328 and BS 8110 or approved equivalent, with a designation of nominal maximum size of aggregate and workability.

Furthermore, the concrete mix shall be designed for durability taking full account of the environment to which it will be subjected.

The maximum total content of acid-soluble chlorides (expressed as Cl) shall not exceed the following limits:

	Cl (ion) content by weight of cement
- Pre-stressed concrete, Heat-cured concrete	0.06% wt
- Concrete made with sulphate-resisting Portland cement	0.15% wt
- Concrete made with ordinary Portland cement/Portland blast-furnace cement	0.30% wt

The maximum total content of acid-soluble sulphates (expressed as calculated SO_3 equivalent) shall not exceed 4.0% by wt of cement in the mix, including the sulphate present in the cement.

The concrete grades shall be selected on the following minimum characteristic strengths at 28 days:

Grade C20	Blinding concrete
Grade C30	All reinforced concrete structures except jetties
Grade C40	Pre-stressed concrete structures and reinforced concrete of marine structures

The maximum Water Cement Ratio (WCR) shall be as follows:

	WCR maximum
Grade 20	0.55
Grade 30	0.45
Grade 40	0.45

4.6 EXPOSURE CONDITIONS

The environments to which concrete is exposed in service can be classified into five levels of severity, i.e. dry, humid (without and with frost), humid in combination with de-icing agents, sea water (without and with frost) and aggressive (weak, moderate, severe or very severe).

Criteria for classification and subsequent requirements for concrete exposed to chemical attack (including recommendation for mix design related to a particular exposure class or condition) are given in [Appendix 1](#).