STRUCTURAL ENGINEERING SOCIETY NEW ZEALAND (INC)

PRECAST CONCRETE - GROUTED CONNECTIONS AND DROSSBACHS - SESOC GUIDANCE

GD#2 : NEW BUILDINGS - SPECIFICATION/CONSTRUCTION/ASSURANCE

PART A : CONSULTING ENGINEERS' PERSPECTIVE

PART B : CONTRACTORS'/SUBCONTRACTORS' PERSPECTIVE

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STRUCTURAL ENGINEERING SOCIETY NEW ZEALAND (INC)

PRECAST CONCRETE - GROUTED CONNECTIONS AND DROSSBACHS - SESOC GUIDANCE

GD#2 : NEW BUILDINGS - SPECIFICATION/CONSTRUCTION/ASSURANCE

RESOLUTION APPROACH - TWO PERSPECTIVES

- **PART A : CONSULTING ENGINEERS' PERSPECTIVE**
- **PART B : CONTRACTORS'/SUBCONTRACTORS' PERSPECTIVE**

GUIDANCE DOCUMENT 2

New Buildings - Specification/Construction/Assurance - Engineer and Contractor Perspective

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1.0 BACKGROUND

1.1 Introductory parts of this paper have included a section on "identification of the existing problem" and signalled the need to promote "work methods to mitigate the recurrence of these problems in future projects".

1.2 This "new construction focus" document is presented in two parts, which are essentially cross-linked via the proposed "quality management" framework.

(a) Part A : How the design engineer, through clauses in the procurement specification, should seek to establish the quality assurance framework for each of those phases.

(b) Part B : How the contractor (together with specialist subcontractors) might respond to that framework in terms of the specific checkpoints in the "off site" and "on site" production and installation process.

These two parts are linked via the operation of the specified quality assurance system, as well as the need to agree "whether the component as designed and as drawn can in fact be built in compliance with the specification", all as further described below.

1.3 Guidance information within Document #2 is presented from both design and construction perspectives in terms of :

(a) compliance requirements arising in the engineers' procurement specification for precast concrete panels :

(i) shop drawings sign offs;
(ii) external face cover to reinforcing;
(iii) embedments including Drossbach ducts, grout sleeves, and associated grouting tubes;
(iv) transport/erection/fit up of panels; and
(v) interconnection, eg by grouting of reinforcing splices within the connections;

(b) contractors' construction method statement arising from the engineer's procurement specification and how outcomes from those are monitored :

(i) specification/QA;
(ii) construction method statements/QC;
(iii) quality management - the QA/QC continuum; and
(iv) construction monitoring; and

(c) The operation of the attached Table 1 in Appendix B showing the main components of the "QA/QC inspection/assurance" template is described further in supplementary papers within the Guidance Document #2 document.

1.4 Because quality assurance (QA/QC) requirement for precast concrete components is in reality a continuum, the specified checkpoints are evaluated alongside each other via a QA/QC inspection/assurance template included within this section which, in part, relies in part on the "construction category" approach used for structural steelwork fabrication and erection in AS/NZS 5131:2016.

A new recommendation will be a specific requirement for a trade-specific construction statement (PS3) for grouting of structural joints acknowledges the associated QA/QC sign offs for this aspect of the works.

This latter part is expected to be of interest to regulators, eg councils, who will (in the normal course of events) prescribe requirements for accepting Producer Statements (PS3, PS4) from those undertaking and verifying the precast concrete installation work, including the grouting of structural connections.

2.0 INTRODUCTION TO PART A AND PART B

2.1 Extent of problem - why is there a concern ?

Industry experience in New Zealand (including investigations of legacy buildings undertaken during seismic performance assessments) have confirmed that :

(a) precast concrete components constructed using Drossbach ducts have low tolerance for set out errors when joining mating parts;

NB : Reported instances of starter reinforcing being "cut off" when they are found to be misaligned with the abutting duct recesses must be of concern in this context.

(b) grouting processes have proved difficult to control, leading (in some instances) to empty or only partially grouted ducts being incorporated in the finished (and signed off) construction;

(c) acknowledging that the majority of precast components incorporating these features involve off-site fabrication, with design engineers being involved in reviewing fabricators' shop drawings; and

(d) providing monitoring of construction via periodic inspections by design engineers (or their representatives) on representative samples of work have not always been effective in identifying often systemic defects in the finished work across the project.

Based on this evidence (both via documented project-specific examples as well as by anecdote), SESOC is now moving to provide design engineers (and others) with specific guidance on this form of construction.

2.2 Is this just a New Zealand problem ?

(a) This is a fair question, particularly if other jurisdictions facing similar issues have already developed solutions.

(b) Referring to parallel experiences within the Australian construction industry reference should be made to the CROSS-AUS Report ID 961 "Grouting of Joints between load-bearing prefabricated concrete members" issued 30/4/21[1]. The section headings within the report underscores well the current issues our TG's guidance is seeking to address, specifically :

(i) Overview of the existing problem;
(ii) key learning outcomes from the Australian experience; and
(iii) clarification of responsibility for design of grouted joints - ie role of the "in-service designer" as defined in AS 3850:2018 Prefabricated Concrete Elements - the role corresponding to that of the "design engineer" in the New Zealand context.

(c) Key messages (paraphrased) for New Zealand within the ID 961 report include :

- *"Whilst all parties involved in the design, documentation, and inspection of grouted joints have a role to play in avoiding failure, the "DESIGN ENGINEER" has particular responsibilities for the design of these joints"*

[1] Link to CROSS (AUS) website : https://www.cross-safety.org/aus/safety-information/cross-safety-report/grouting-joints-between-load-bearing-prefabricated-961 - refer attachment ex SESOC Journal page 75.

and

- *"It is the "DESIGN ENGINEER'S" responsibility to design, specify, and document correctly the performance requirements for grouted joints"*

and

- *"With precast concrete construction, the crucial part of the system is (generally) the "grouted joint" where all the design actions are transferred through a very small area"*

and

- *"It is important that the builder/contractor correctly follows the (specified) design and details (for the grouted joint) by having a documented QA procedure.*

(d) This report highlights the risk of failure of grouted joints to precast concrete if they are not designed, specified, and installed correctly with the Australian environment and its recommendations particularly relevant to the "high seismic load demand" environment existing in New Zealand.

(e) During the course of our preparing this guidance, our Task Group was urged by some within the consulting engineering sector to not see their role as being more than a specifier for a "performance-based procurement". Unpicking this advocacy, it was clear that those urging this approach saw their having specified a joint to be "fully grout filled" within a quality assured installation framework, then from their construction monitoring perspective that was the end of the matter. For avoidance of doubt, the members of our Task Group totally reject this approach, and take the view that having specified that a quality management system be applied to the construction of the grouted joint, then the design engineer has an obligation to verify that the system specified is operating effectively (by inspection, sampling, or other means).

2.3 "Designed" versus "Specified" elements and/or systems

(a) Whilst this guideline convers "grouted structural joints' in general, it references two particular types, viz "Drossbach ducts" and "proprietary grout sleeves", essentially requiring the design engineer to adopt different design approaches to design (or "performance verification") in each case.

(b) For the purposes of differentiation, we have identified these as :

(i) "designed elements" (encompassing "Drossbach" duct grouted connections); and/or
(ii) "specified elements" (encompassing components within some of the currently available proprietary grout sleeve systems)

- and considered how each might be used by design engineers when seeking to identify the most appropriate pathway to structural - ie clause B1 - compliance.

(c) It is normal for proprietors of the "specified elements" to seek certification of their products via "CodeMark" under Part 3/sub-part 7 "Product Certification" of the Building Act. Reference should be made to Building Act sections 268-271 plus associated regulations for the applicable certification framework in each case.

(d) We believe it important for design engineers to consider carefully the distinction between these approaches, particularly where alternative solutions outside B1/VM1 pathway are required.

(e) To assist design engineers, and where appropriate product certifiers, we have set out in Table DG#2.1 entitled "Performance-Related Attributes for Grouted Joint Connection Systems" the various matters that we consider need to be evaluated by them when design solutions outside the B1/VM1 framework are contemplated.

2.4 Refer Table GD#2.1.

2.5 So what are New Zealand-based producers saying about this issue ?

Firstly, we offer the consulting engineer's perspective as per the following Part A papers entitled "Consulting Engineers' Perspective" authored by Barry Brown and Warren Lewis.

TABLE GD#2.1 "Performance-Related Attributes for Grouted Joint Connection Systems"				
Item	**Activity**	**Key performance-related attribute**	**How particular grouted connection type/system might deliver on this attribute**	**Remarks**
1	Categorisation	Design compliance method	Either as : (a) **designed component** - ie specifically-designed system whose dependable performance is via cited verification method, with as-built performance based on derating allowances for construction-related variability; or (b) **specified component** - ie certified system whose dependable performance is rated via series of type tests with as-built performance based on installation complying with prescribed assembly of components and installation method.	Requires design engineer to assess limitations of type tests for specified components where benchmarked against the equivalent designed components.
2	Panel joint design	Design concept used to transfer forces through joint to be identified	Method of transferring primary forces through joint described with comparable capacities evaluated using either : (a) specific design to relevant design standard, eg NZS 3101:2006 Amt 3 rule; or (b) appropriate type testing where use of these is permitted by relevant design standard.	Design engineer relies on third party certifications for components ability to resist specified test loads
			Secondary load transfer effects on panel zone adjacent to joint to be evaluated by designer and appropriately reinforced.	Design engineer required to assess secondary load transfer effects if grouted joint on enclosing wall panel in all cases.
			Designer reliance on annular (or other) spaces between reinforcing splice bars and enclosed wall panel being filled void free with appropriately specified HS grout.	Design engineer relies on complete/verifiable grout installation to ensure structural performance of joint.
3	Panel joint design	Robustness : protection against brittle behaviour	Use of cited verification methods, eg NZS 3101:2006 Amt 3, as basis for demonstrably compliant design. Prescribe use of pre-qualified materials and methods to form the joint that ensure essentially ductile behaviour in all likely environmental conditions - ie verified impact resistance of steel components across a range of strain rates and/or service temperature.	Design engineer needs to assess transferability of proprietary type test into actual design situation.

TABLE GD#2.1 "Performance-Related Attributes for Grouted Joint Connection Systems"				
Item	**Activity**	**Key performance-related attribute**	**How particular grouted connection type/system might deliver on this attribute**	**Remarks**
4	Panel joint design	Designer-specified overload margins	For specified systems, the design engineer needs the ability to incorporate joints components with certified strength/deformation margin above overstrength thresholds within the connected reinforcing steel. This enables specifier to incorporate additional strength/robustness allowances for unforeseen design conditions beyond those included in the components suppliers type test.	Design engineer may require such additional margins at particular location within the structure, such as base joints or potential plastic hinge zones in wall panels designed for limited ductile behaviour.
5	Panel joint fabrication/installation	Tolerances : available margins for variations in fit up	Designer to acknowledge intended construction sequence and makes adequate provision for reasonable construction tolerances accordingly within the grouted joint ref NZS 3109. This requirement recognises reality that precast wall panel (and similar) component will essentially concentrate most of dimensional variation at the interface joints which are subsequently intended to transfer design loads after they are grouted.	Design engineer sign off approval for fabrication drawings need to reference required (and available) fit up tolerances.
6	Panel joint installation/building in	Grout filling verification	Grouting methodology requires design engineer approval with regard to : (a) strength/workability of grout material; and (b) defect-free grout placement - including adequate verification checks for each. Visual observation of grout placement is normally required.	Refer attributes separately identified under quality assurance.
7	Panel joint inspection/assurance	Ease of post-grouting inspections/verification	Design engineer to consider viability of the various inspection methods likely to be available to contractor to verify sufficiency/completeness of grout filling operations, including : (a) non-invasive inspections, eg ultrasonic; (b) invasive inspections, eg drilling; and/or (c) other methods.	Post-grouting verification methods will normally form part of grouting method statement approved by design engineer.

TABLE GD#2.1 "Performance-Related Attributes for Grouted Joint Connection Systems"				
Item	**Activity**	**Key performance-related attribute**	**How particular grouted connection type/system might deliver on this attribute**	**Remarks**
			Consideration to include materials form the grouting void are likely to impede the effective use of the above verification inspections.	
8	Panel joint / defect repair	Ease of post-grouting defect remediation	Design engineer needs to consider the practicality of particular remediation methods for insufficiently grouted joints should defects be identified in the completed work. Some metal formers used to form voids in precast panels readily accommodate eg invasive inspection via drilling, whilst those in other materials do not. Consideration of this attribute required to be included as part of item 7 above.	Covers construction realities that some grouted joints will be identified as being defective after installation.

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GD#2 : NEW BUILDINGS - SPECIFICATION/CONSTRUCTION/ASSURANCE

PART A : CONSULTING ENGINEERS' PERSPECTIVE

[A] PART A : CONSULTING ENGINEER'S PERSPECTIVE - SPECIFICATIONS AND PROCUREMENT

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A1. BACKGROUND

A1.1. This part of Guidance Document 2 covers "Specification and Procurement" from the structural engineering/specifier's perspective, on the basis that :

(a) the engineer has designed the works in the knowledge that precast components therein will be manufactured off site and has prescribed (via the technical specification) the full as-constructed form, including how they will be built, plus associated quality assurance requirements;

(b) construction monitoring will be required by all the producers involved, with the focus in this case being on precast concrete components, and the site jointing of those by grouting; and

(c) because "mating parts" are involved, a second focus will be on the set out and construction on site so as to facilitate the accurate joining of those components.

A1.2. Contents of this Part A document

This part comprises five separate papers entitled :

(a) Guidance Document 2.1(a) "Quality Assurance - Key Stages of Inspection/Monitoring"

(b) Guidance Document 2.1(b) "Method Statement for Drossbach Duct Grouting - Default Provisions"

(c) Guidance Document 2.1(c) "Method Statement for Proprietary Coupler Sleeve Grouting - Default Provisions"

(d) Guidance Document 2.1(d) "Precast Wall Panels : Elimination of Short Cover"

(e) Guidance Document 2.1(e) "Procurement Specification - Key Headings"

A1.3. When read together, these papers are intended to describe a "Specification/Construction/Assurance" continuum which, if followed, will give the building owner and the regulator confidence in the compliance of the finished construction with the design, which is (via the building consent) deemed to satisfy the structural performance provision of the Building Code clauses B1 and B2.

GUIDANCE DOCUMENT 2.1(A)

QUALITY ASSURANCE - KEY STAGES OF INSPECTION/MONITORING

TECHNICAL PAPER 2.1(A) : QUALITY ASSURANCE - KEY STAGES OF INSPECTION/MONITORING

1.0 INTRODUCTION

1.1 The technical aspects of the Drossbach Duct/Grout Sleeve Task Group's work regarding the construction of precast concrete wall panels will cover four areas, each to be addressed separately -

(a) First Part – construction of the supporting foundation (or floor slab) or previous construction incorporating the vertical "starter" (or connection) reinforcing projecting upwards.

(b) Second Part – manufacture of the precast wall panel, typically manufactured in a factory and transported to site, which incorporates the horizontal joints to be formed using Drossbach ducts as splice joint void formers.

(c) Third Part – the "mating" of the wall panel base into the foundation as it is erected and temporarily supported.

(d) Fourth part – the grouting of the Drossbach ducts/grout sleeves to form the splice in the vertical reinforcing, including the grouting of the space beneath the base channel joint to integrate the base of the wall panel with the supporting foundation.

1.2 This Technical Paper 2.1(a) : "Quality Assurance – Key Stages in Inspection and Monitoring", aims to link together these separate parts, by considering requirements for quality management during five separate stages of construction viz :

(a) Stage PC #1 – Panel Shop Drawing Review

(b) Stage PC #2 – Pre-construction Panel Inspection

(c) Stage PC #3 – Foundation Projecting starter set-out check

(d) Stage PC #4 – Panel Erection/Stability/Alignment inspection

(e) Stage PC #5 – Grouting of Base Joint and vertical Drossbach ducts/grout sleeves

(f) Stage PC #6 – Quality Assurance sign offs for all the above

1.3 Technical Paper 2.1(b) "Method Statement for Drossbach Duct/Grout Sleeves Grouting" seeks to address particular requirements of stage PC #5 which we consider to be the main focus of our Task Groups work, but is dependant in good part on the previous stages PC #1 through PC #4 being carried out correctly by the contractors/subcontractors concerned.

1.4 It is anticipated that subsequent paper(s) in this Part A will address other aspects of PC #1 thru PC #6 where further commentary is considered appropriate for the work concerned.

2.0 BASIC ASSUMPTIONS RELATING TO PANEL MANUFACTURE

2.1 Design engineer's documentation will have confirmed:-

(a) technical requirements for materials and workmanship relating to the manufacture of precast panels to the engineer's design as per items 1.1(b), (c), and (d) above;

(b) requirements on the main contractor to establish a quality assurance programme cover all stages within item 1.2 above; and

(c) identified the various "check points" established by the above programme which involve monitoring inputs from the design engineer and the "expectations" associated with that design engineer involvement as compared with those of the other parties.

2.2 The "expectations" referred to within (b) above will take account of the statutory responsibilities of each party to the process as prescribed by sections 14D through 14G of the Building Act, which are discussed further within Table 1 "Inspection/Assurance Template" reproduced in Appendix B of this paper.

2.3 Fabricator/main contractor/design engineer's documentation when read together for panel manufacture will confirm details for:-

(a) grouting method (default to 3 stage method if not stated);

(b) grout tube inlet/outlet tube features and function (configured to suit grouting method);

(c) horizontal formwork required for the horizontal base interface joint; and

(d) quality assurance tests to be undertaken for "grouting - completed" sign off.

3.0 STAGE PC #1 : SHOP DRAWING REVIEW (design engineer)

3.1 Objectives

Ensure the Drossbach duct length and diameter as installed is the correct dimension to reflect :

(a) required length* of reinforcing to be bonded, including allowance for accumulating vertical tolerances; and

(b) required thickness of annulus space for grouting, including accumulating horizontal tolerance

- all as specified by the design engineer via the plans and specifications and proposed via the fabricator/main contractor via the shop drawings.

*NB : This should include any "overlength" of Drossbach duct required by the main contractor to accommodate eg intended variation in projecting lengths of particular reinforcing bars required to assist alignment of panels over the foundation during erection - refer item 5.2 later.

3.2 Objective

Ensure Drossbach duct or grout sleeves are correctly positioned in wall panel to suit :

(a) vertical reinforcing splice dimensions and positioning; and

(b) exposed surfaces "cover to reinforcing" requirement

- all being the responsibility of fabricator/main contractor.

3.3 Actions - Confirm Drossbach Duct/Grout Sleeve positioning :

(a) along length of wall - end distances and spacing;

(b) through thickness wall - cover to external/internal faces; and

(c) vertically in wall - sufficient length for reinforcing to insert.

3.4 Actions - Confirm reinforcing within panel is as per designer's drawings, with particular emphasis on :

(a) ensuring reinforcing cover achieved within panel either side of Drossbach ducts/grout sleeves; and

(b) ensuring reinforcing cover (particularly where doubly reinforced) is achieved elsewhere in the panel

- including deductions required to accommodate architectural and other requirements, eg cast-in embedments, aesthetic profiling, and/or rebates in concrete surface, etc.

(c) Confirm special reinforcement screw-in assembly require for grout sleeves, including epoxy void filling of threads where this is a requirement of the supplier's certification.

4.0 STAGE PC #2 : PRE-CONSTRUCTION INSPECTION OF CONCRETE PANEL FORMS (fabricator and/or main contractor's representative)

4.1 Objectives

Ensure Drossbach ducts/grout sleeves are correctly positioned in wall panel to suit :

(a) vertical reinforcing splice dimensions; and

(b) exposed surfaces "cover to reinforcing" requirement

- all being the responsibility of fabricator/main contractor.

4.2 Confirm available clear cover to (particularly) horizontal reinforcement over Drossbach ducts/grout sleeves to each face, eg :

(a) external face; and

(b) internal face

- meets requirements of engineer's specification.

NB : If not stated, then default to requirements of NZS 3109:1997 cl 5.1-5.3 and Table 5.1.

4.3 Confirm accuracy of placement of reinforcing within panel as specifically :

(a) primary eg vertical reinforcing;

(b) primary eg horizontal reinforcing;

(c) Drossbach ducts/grout sleeves* dimensions and positions to receive splices to vertical panel reinforcing;

(d) assembly and epoxy void filling of any screwed-in bar, including epoxy curing;

(e) other reinforcing* connections/connectors;

(f) embedments, eg weld plates;

(g) secondary eg confinement reinforcing; and

(h) in-situ pour strips (for splices to horizontal panel reinforcing).

*NB : Include for installation of tubes for later grouting and/or inspection, as per precaster's standard details.

4.4 Confirm special requirements for formwork, including eg construction joints :

(a) Surface preparation method (specified)

(b) Surface roughness amplitude (nominated) default 2 mm

4.5 Provision of "Running Dimension Set Out" drawing or template

Because panel installation will generally involve the "mating" of projecting starter reinforcing with Drossbach ducts or grouting sleeve inserts that do not incorporate a full tolerance provision as per NZS 3109:1997, additional checks will be required to ensure the intended "fit up" does occur.

The following questions need to be addressed by the panel fabricator and/or main contractor before casting the panel -

Q1 : Will panel fabricator provide the main contractor with "running dimension set out sheet" to assist the placement of vertical starter reinforcing in the supporting foundation ?

Q2 : If not, will a "Drossbach Duct/Grout Tube Interface Template" to be supplied by the panel fabricator and/or main contractor as part of the procurement ?

If either is not supplied by fabricator, main contractor needs to specify how fit-up tolerances are to be verified within panel support surface, and agree same with the design engineer.

4.6 Fabricator to verify achievement of specified covers depth to reinforcement on a pre-agreed sampling (or other) basis, particularly in the panel zones occupied by Drossbach tubes or grout sleeves within the finished construction by undertaking magnetic and/or ultrasonic scanning of specifically :

(a) clear cover to what will be exposed external wall surfaces; and

(b) other surfaces where reinforcing cover is deemed critical by the design engineer.

5.0 <u>STAGE PC #3 : FOUNDATION/FLOOR - INSTALL PROJECTING STARTER REINFORCING AND PREPARE SUPPORTING CONCRETE INTERFACE (main contractor/design engineer)</u>

5.1 Objectives

Timely identification of any lack of fit-up of mating parts before suspended wall panel is craned down over projecting vertical reinforcing.

5.2 Confirm horizontal support interface checks are undertaken (pre-panel erection)

(a) *Starter reinforcing position (edge/end distances, spacing)

(b) Starter reinforcement projection (lap splice)**

(c) Surface roughness amplitude 2 mm (using separately specified method)

*NB : Use "Running Dimension Set Out" drawing as one method for satisfying this requirement.

**NB : May include contractor-specified "overlength" in some starter reinforcement to facilitate panel erection - refer item 3.1 previous.

5.3 Confirm horizontal bearing support checks are undertaken (pre-panel erection)

(a) Panel support shims correctly located

(b) Grout seal formwork available

NB : Typical base shim height for base channel grouting to be 20 mm.

6.0 STAGE PC #4 : PRECAST PANEL - ERECTION/STABILISED (ready for grouting of vertical splices) (panel installer/main contractor)

6.1 Objectives

Panel erected and supported in its final position, stabilised, and ready for completion of splices.

6.2 Propping/panel stabilisation completed as per specialist installer's HSE* etc requirements, viz :

(a) stability during construction (HSE); and

(b) positioning within tolerance

- ready for grouting completion of splices (vertical and/or horizontal).

*NB : This will normally include reference to Worksafe NZ best practice guide and/or Precast NZ handling/erection guidelines.

7.0 STAGE PC #5 : PRECAST WALL PANEL - GROUTED VERTICAL SPLICES (grouting subcontractor/main contractor/design engineer)

7.1 Objectives

To provide adequate levels of vertical support and/or base shear resistance by completing splice joint incorporating high strength grout sufficient to achieve.

7.2 Horizontal bearing support checks (pre-panel erection)

(a) Panel support shims correctly located

(b) Grout seal formwork available

(c) Bearing surface profile is roughened and clean

(d) Bottom of panel surface profile is roughened and clean

7.3 Ensure, by visual inspection, that any Drossbach duct/grout sleeve interface template used at earlier stages of construction has been extracted from the wall/floor interface zone.

7.4 Main contractor to supply to design engineer for approval :

(a) grouting method statement (by grouting subcontractor); and/or

(b) proposed means of assuring sufficiency of completed grout installation undertaken in accordance with that method.

7.5 For Drossbach duct connections, unless specified otherwise, complete interface/Drossbach duct grouting in three stages as :

(a) First Stage, viz "base channel grouting" - 20 mm base channel, extending say 25 mm up into ducts sufficient to seal the base;

(b) Second Stage, viz "duct/sleeve grouting" - grout ducts over full height, leaving 50 mm ungrouted "closure zone" at top; and

(c) Third Stage, viz "topping up" of duct closure zone - by solid plastering or other approved method.

NB : Required grout volume to exceed 95% of total void space available volume by calculation with misclose being concentrated within the Stage 3 close off zone. Variations from this procedure may be sought, but the acceptance threshold based on 95% void space limit will still apply.

Refer Appendix D Figure 1 graphic included for explanation of the default "three stage" grouting method.

7.6 For proprietary grout sleeve connections, the grouting requirements of the proprietor's installation specification should be followed for all stages of the work.

Notwithstanding the above, it is expected that best grouting practise with proprietary grout sleeves will involve :

(a) first stage, viz "base channel grouting" - 20 mm base channel extending up sufficiently to seal the base;

(b) second stage, viz "sleeve grouting" - grout sleeve over full height until annulus/void is full with grout.

Third stage grouting does not apply with grout sleeves as the tensile capacity of the grouted bar is dependent on the annulus void being 100% filled with grout without any voids over the full length of the sleeve.

NB : Accordingly, the 95% void filling requirement applicable for Drossbach ducts see item 7.5) does not apply to grout sleeves.

7.7 Unless specified otherwise, grouting subcontractor provide sufficient records, eg grout volumes to verify sufficiency filling of base channel and all ducts/sleeves.

NB : Fabricator/main contractor/design engineer's documentation to include sufficient details to identify :

(a) nature/extent/mix proportions and strength of grout to be used as infill to wall base and Drossbach duct/sleeve splice zones;

(b) specified condition, eg strength, roughness of the interface zone, required to generate shear friction;

(c) QA/QC requirement for grouting as basis for sign off; and

(d) assurance of void elimination via eg grout volume checks, test drilling of sample ducts, and/or other methods.

7.8 Refer Appendix D for information on available non-destructive investigation methods which can be used to verify the sufficiency of grout filling with Drossbach ducts and/or proprietary grout sleeves.

8.0 <u>STAGE PC #6 : QUALITY ASSURANCE - SIGN OFF (main contractor/design engineer)</u>

8.1 Objectives

To provide sufficient QA sign off documentation to allow :

(a) main contractor to issue relevant Producer Statements - Construction, viz PS3, relating to construction; and

(b) design engineer to issue relevant Producer Statements, viz PS4, relating to monitoring of construction.

NB : This will, by necessity, incorporate the contractor's PS3.

8.2 It is assumed that the Regulatory Authority will normally require evidence to be provided from parties responsible via Producer Statements.

8.3 In this case, the Regulating Authority will likely require specific sign offs for each of the above construction stages PC #1, PC #2, PC #3, PC #4, and PC #5 as described above.

9.0 DESIGN ENGINEER INVOLVEMENT - CONSTRUCTION MONITORING

9.1 The following description of "construction monitoring" is taken from Appendix 3 of the ACENZ/IPENZ document "Guideline on the Briefing & Engagement for Consulting Engineering Services" (January 2004), hereinafter referred to as the "CM Guide".

> *Construction monitoring*
> *The consultant usually assists in monitoring the quality of work undertaken or goods provided by a contractor. This service may be required in place of, or in addition to, any quality assurance programme provided by the contractor. It provides an independent assessment of the quality of the contractor's output.*
>
> *The extent of monitoring of the project works significantly affects the risk of under strength materials and/or poor quality workmanship being incorporated into the project. A high level of quality monitoring may be particularly important in reducing the risk of latent defects which may become apparent only at a later stage in the life of the project. Increased levels of quality monitoring usually involve higher cost for the client and there is therefore a need to strike a balance in selecting the appropriate level for the work involved in the project. The degree to which the consultant is engaged will depend on the level of quality monitoring required and also the extent to which the contractor is able to provide or arrange suitable independent monitoring.*
>
> *The extent and type of service required will also vary, depending on the type of project being undertaken. Definition of five levels of construction monitoring are defined in Appendix 4. This system can be readily adapted to situations other than construction and provides a starting point for discussions between the client and the consultant in determining the scope of service required from the consultant.*
>
> *Any statement or certification given by the consultant in respect of the quality of the completed works will be reliable only to the extent of the consultant's engagement for monitoring of construction.*

9.2 Appendix 4 "Construction Monitoring" of the CM Guide makes the point that not all projects are equal, and allows design engineer and their clients to assess the level of construction monitoring (CM) required for a particular project based on several factors.

> *Five levels of construction monitoring service are defined in Table A4(i).*
>
> *The appropriate level will be project dependent, influenced by:*
>
> - *the size of the project;*
> - *the importance of the project;*
> - *the complexity of the construction works;*
> - *the experience and demonstrated skill in quality management of the contractor.*
>
> *The primary responsibility for completing the contract works in accordance with the requirements of the plans and specifications is the constructor's.*
>
> *The involvement of the consultant is important during the construction phase to ensure that:*
>
> - *the design is being correctly interpreted,*
> - *the construction techniques are appropriate and do not reduce the effectiveness of the design and*
> - *the work is completed generally in accordance with the plans and specifications.*

The risk of non-compliance can be reduced by increasing the involvement of the consultant. Because the cost of monitoring increases with increasing levels of service the client should consider all factors before deciding upon the most appropriate level of construction monitoring for the project.

NB : Text above is extracted from original 1997 version of CM Guide and is included here due to its fuller description of the CM obligation from the later (2004) version.

9.3 It is important to note here that the CM Guide discusses construction monitoring input levels for projects as a whole rather than for individual components within a structure. Accordingly, the design engineer, having identified and agreed the CM level required for the project as a whole, might then need to consider requirements for specific parts of the project using the same "factors" as listed in the panel above in order to better target the application of the construction monitoring input to specific parts of the project.

In this case, the applicable "influencing" factors might be re-specified as follows :

- The size and/or number of components
- The importance - ie criticality - of the components concerned and the consequences of non-conformity
- The complexity of the construction works
- The experience and demonstrated skill in quality management of the contractor

9.4 In the case of precast concrete wall panel components incorporating vertical stitching of reinforcing steel using grouted ducts/proprietary sleeves, the following input levels might be expected for the design engineer (DE) responsible for monitoring manufacture/installation :

(a) Monitoring level for DE to be applied project wide = CM3 (evaluated from CM guideline).

(b) Component monitoring level for DE to review manufacture/installation of precast concrete wall panel :

(i) Establish applicable QA/QC processes for panel manufacture/installation involving inputs from MC/PS/GR/DE = CM4*
(ii) Shop drawings review for each precast concrete component involving inputs from MC/PS/DE = CM5
(iii) Panel construction/inspection (involving inputs from MC/PS/DE) = CM2*
(iv) Panel delivery/installation (excluding grouting) involving MC/PS/DE = CM2*

(c) Component monitoring level for DE to review installation of foundation/slab support :

(i) Placement of reinforcing (MC/DE) = CM3*
(ii) Support surface roughness (MC/DE) = CM4*

(d) Component monitoring level for DE to review installation of grouted joint :

(i) Panel joint grouting (involving inputs from MC/PS/DE)
- Trial/proof of grouting procedure = CM2*
- Verification by production sampling of completed grouting = CM3/CM4*

*NOTE : These CM levels involving DE will be reduced where the client has engaged an independent party to provide the necessary quality assurance/control including verification reports on same. These reports will normally include evidence of post-construction testing undertaken, eg non-destructive and/or invasive inspections, plus grout volume verification checks.

9.5 The inspection/assurance template attached at Appendix B/Table 1 of this guide presumes that, in the general case, the above CM levels will be applied.

10.0 APPLICATION OF AS/NZS 5131:2016 CONSTRUCTION CATEGORY-BASED PRINCIPLES TO QA/QC SYSTEMS FOR PRECAST CONCRETE

10.1 In developing a QA/QC framework for precast components, eg wall panels incorporating Drossbachs/sleeves, which takes into account the abovementioned "influencing factors", we need to acknowledge the "construction category" approach already developed for fabrication and erection of structural steelwork in the recently cited AS/NZS 5131:2016 document.

NB : "Structural steelwork - Fabrication and erection" AS/NZS 5131:2016 which was cited under BA19 in the most recently published issue of B1/VM1 (Amendment 19 dated 28 November 2019).

10.2 A review of Appendix C and Appendix B of the AS/NZS 5131 document sets out :

(a) in Table C4, guidance on determination of the "construction category" in accordance with prescribed parameters (CC1 through CC4); and

(b) in Tables B1 through B4 information requiring to be included, list of responsibilities to be allocated, all in terms of the relevant construction categories (CC).

10.3 Consideration of this standard this leads us to the view that henceforth we need to :

(a) ensure the structural specifications for precast incorporating site-grouted Drossbach/Sleeve-type splices for reinforcing include QA/QC references to AS/NZS 5131:2016-type (or equivalent) requirements;

(e) ensure that plans and specifications include provision of a "construction category" for both the overall building design and individual precast concrete components within it; and

(c) revise/develop a proforma "standard materials and workmanship specification" (particularly the QA/QC parts therein) to ensure future precast concrete designs incorporating Drossbach duct/grout sleeve splicing are fit for purpose in this regard.

11.0 APPENDICES

11.1 Refer Appendix A attached for Extracts from Building Act 2004 (BA04) Section 14 "Responsibilities of Parties undertaking building work".

11.2 Refer Appendix B attached for Table #1 ‘Inspection/Assurance template’ being a short-form summary showing the intended use of the above-referenced requirements from items 1-8 above.

NB : Appendix B formulation presumes that design engineer has incorporated within the plans and specifications the quality management framework for the project construction categories for all precast components to be supplied for the structure, and is applying relevant QA processes to those components throughout all stages of production/delivery/installation.

11.3 Refer Appendix C attached for standard details for precast wall panels incorporating preformed ducts for grouting of vertical splices along the base of the panel.

Ref standard detail - Figure 1 "Drossbach Duct Grouting undertaken in Stages" to be read alongside :

(a) procedures specified for 3-stage grouting of Drossbach ducts at Step PC#5 (item 7) of this paper; and

(b) proprietary grouting manufacturer's Guides for Specification and Installation of their product.

11.4 Refer Appendix D for information on available non-destructive investigation methods which can be used to verify the sufficiency of grout filling with Drossbach ducts and/or proprietary grout sleeves.

APPENDIX A: EXTRACTS FROM BUILDING ACT 2004 (AS AMENDED 2012)

A1:- Section 14D : Responsibilities of Designer

(1) In subsection (2), the designer means a person who prepares plans and specifications for building work or who gives advice on the compliance of building work with the building code.

(2) A designer is responsible for ensuring that the plans and specifications or the advice in question are sufficient to result in the building work complying with the building code, if the building work were properly completed in accordance with those plans and specifications or that advice.

A2:- Section 14E : Responsibilities of Builder

(1) In subsection (2), builder means any person who carries out building work, whether in trade or not.

(2) A builder is responsible for :

(a) ensuring that the building work complies with the building consent and the plans and specifications to which the building consent relates;
(b) ensuring that building work not covered by a building consent complies with the building code.

(3) A licensed building practitioner who carries out or supervises restricted building work is responsible for :

(a) ensuring that the restricted building work is carried out or supervised in accordance with the requirements of this Act; and
(b) ensuring that he or she is licensed in a class for carrying out or supervising that restricted building work.

A3:- Section 14F : Responsibilities of Building Consent Authority

A building consent authority is responsible for :

(1) checking, in accordance with the requirements of this Act for each type of building consent, to ensure that :

(a) an application for a building consent complies with the building code;
(b) building work has been carried out in accordance with the building consent for that work;

(2) issuing building consents and certificates in accordance with the requirements of this Act.

A4:- Section 14G : Responsibilities of Product Manufacturer or Supplier

(1) In subsection (2), product manufacturer or supplier means a person who manufactures or supplies a building product and who states that the product will, if installed in accordance with the technical data, plans, specifications, and advice prescribed by the manufacturer, comply with the relevant provisions of the building code.

(2) A product manufacturer or supplier is responsible for ensuring that the product will, if installed in accordance with the technical data, plans, specifications, and advice prescribed by the manufacturer, comply with the relevant provisions of the building code.

APPENDIX B: TABLE #1 : INSPECTION/ASSURANCE TEMPLATE

MAIN CONTRACTOR [MC]	PRECAST SUPPLIER [PS]	GROUT SUBCONTRACTOR [GR]	INSPECTION/ TEMPLATE REF	MONITORING RESPONSIBILITIES		
				MAIN CONTRACTOR [MC]	ENGINEER [DE]	COUNCIL [BCA]
A. PRECONSTRUCTION PHASE NB : Refer Explanatory Note "Expectation - Checkpoint A" below.						
A1.	Panel supply	Shop drawings	Interpretation of design requirements	PC1	Establish/check process	Engineer approval PC1 (CM1)	(a) Notify producers of BCA's "reasonable grounds" expectation for precast component sign off based on eg AS/NZS 5131:2016 construction category evaluation. (b) Clarification with MC, DE of : (i) extent of BCA's intended reliance on producer's sign offs, eg specified QA/QC plus PS3-PS4; and (ii) BCA's expectation of DE's monitoring involvement, viz clarification of CM levels. (c) Interpret BCA's building consent conditions (if unclear).
A2.	Erection/stability and grouting		Method statement incl QA/QC	PC4 PC5	Establish/check process	Engineer approvals PC4/5 (CM1)	
A3.	Foundation/slab support			PC3	Foundations/wall Wall interface fit up pre-check Establish/check process	Engineer approvals PC3 (part CM3)	

Expectation - Checkpoint A

(a) Establish construction methods and verification processes with all producers involved, including deciding relevant eg "construction categories", and obtain BCA agreement to same.
(b) Confirm how procedures for verification/conformity against targets pre-agreed at progressive construction stages, including construction monitoring (CM) level, are intended to be operated by design engineer and/or by independent quality assurance operative engaged for the purpose by the owner.
(c) Take into account the various planning - construction assurance sign off obligations on each producer that will apply at Checkpoint C.

TECHNICAL PAPER 2.1(A) : QUALITY ASSURANCE - KEY STAGES OF INSPECTION/MONITORING

	MAIN CONTRACTOR [MC]	PRECAST SUPPLIER [PS]	GROUT SUBCONTRACTOR [GR]	INSPECTION/ TEMPLATE REF	MONITORING RESPONSIBILITIES		
					MAIN CONTRACTOR [MC]	ENGINEER [DE]	COUNCIL [BCA]
B.	**CONSTRUCTION PHASE**	NB : Refer Explanatory Note "Expectation - Checkpoint B" below.					
B1.	Panel manufacture	Assembly and inspection		PC2	PS/MC field checks	Engineer approval CM3	(a) Undertake periodic inspections (equivalent CM1/other) level to verify effective operation of specified QA/QC systems referred to under A above. (b) Feedback - Inform MC, DE of observed non-conforming building work or their monitoring thereof.
		Concrete casting		PC2	PS/MC field checks and issue PS3		
B2.	Foundation/slab support			PC3	Foundations/wall Wall interface fit up post-check MC verify results	Engineer approvals PC3 (part CM3)	
B3.	Panel installation	Position and fit up		PC4	PS/MC field checks	Engineer approval (Part CM3)	
B4.	Panel grouting	Verify Method Statement operating	Grouting proof testing	PC5	MC verify process/review results	Engineer approval (Part CM3)	
		Verify QA/QC by sampling/other	Grouting QA	PC5	MC review results and issue PS3	Engineer approval (Part CM3)	

Expectation - Checkpoint B
(a) Verify that methods and verification processes established under Checkpoint A above are understood by all producers and are operating effectively.
(b) Use mix of "trial installation", "proof testing", and/or "sampling of work produced" to provide "reasonable grounds" assurance that pre-agreed conformity targets are being met.
(c) Identify non-conformities as they occur, and identify means of remedying these.

C.	**PLANNING - CONSTRUCTION/ASSURANCE/SIGN OFF PHASE**		NB : Refer Explanatory Note "Expectation - Checkpoint C" below.				
C1.	QA/QC system	Supply/confirm	Supply/confirm	PC1-PC5 requirements	List information required/provided	Collate/review QA/QC records from MC/DE as per Stages A, B and issue PS4 (with attachments) if satisfied as to conformity.	(a) Review BCA records from A, B above. (b) Receive "listed information" including PS3, PS4 plus other QA/QC reports from third parties as part of CCC application (Form 8).
C2.	Foundation/slab support	N/A	N/A	Provide/record PC3	List information required/provided		
C3.	Panel supply	Provide PC1/PC2	N/A	Provide/record PC1, PC2	List information required/provided		
C4.	Panel install	N/A	N/A	Provide/record PC4	-		

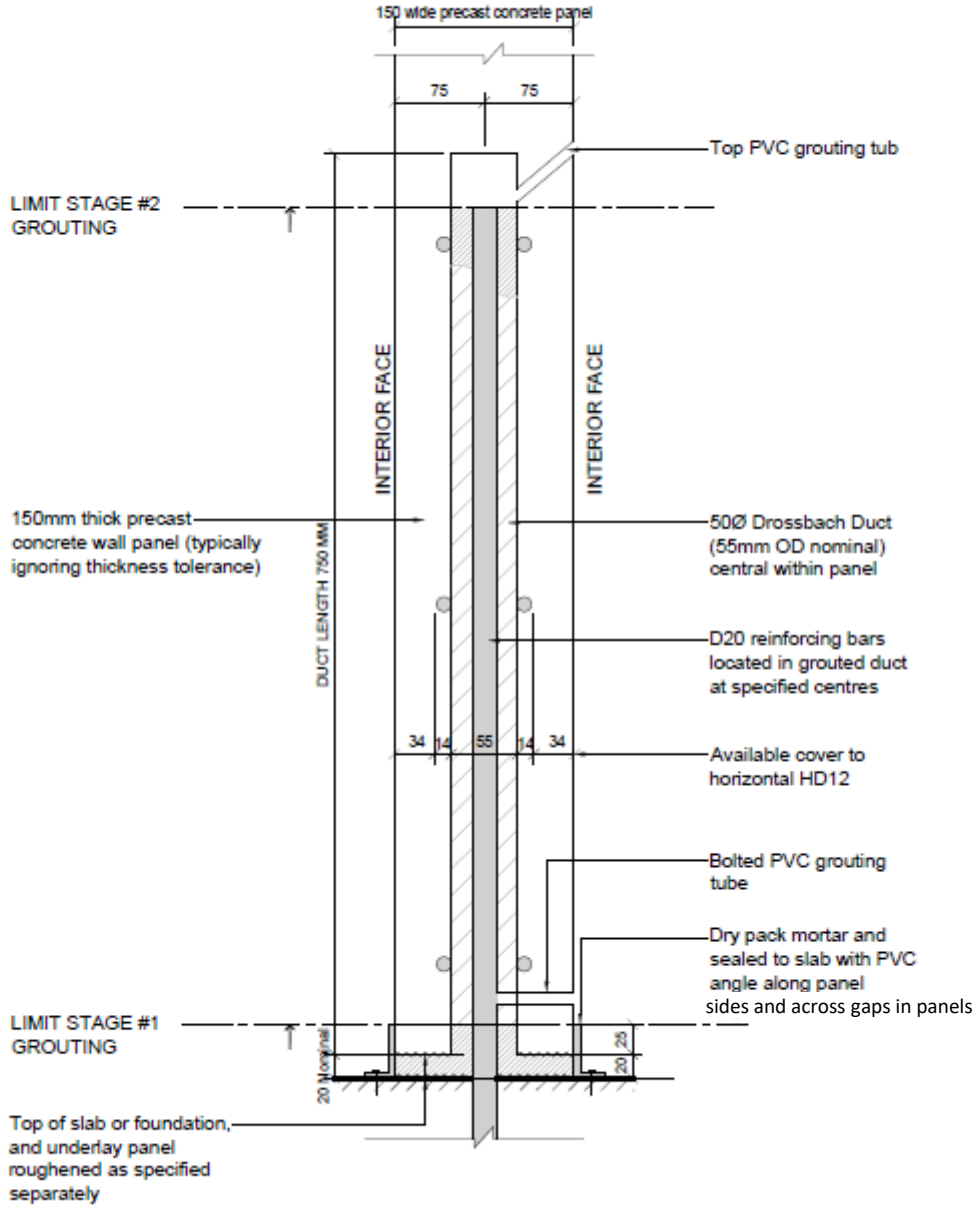
TECHNICAL PAPER 2.1(A) : QUALITY ASSURANCE - KEY STAGES OF INSPECTION/MONITORING

	MAIN CONTRACTOR [MC]	PRECAST SUPPLIER [PS]	GROUT SUBCONTRACTOR [GR]	INSPECTION/ TEMPLATE REF	MONITORING RESPONSIBILITIES		
					MAIN CONTRACTOR [MC]	ENGINEER [DE]	COUNCIL [BCA]
C5.	Panel grouting	N/A	Supply/confirm	Provide/record PC5	List information required/provided		

Expectation - Checkpoint C

(a) Confirm upfront the form/content of sign off QA/QC documentation with design engineer/monitoring engineer and/or Council inspectors, all as per Checkpoints A and B above.
(b) Producer Statements - Construction (PS3) to include relevant inspection sheet, QC inspection/test results relating to the building work from supplier/installers involved.
(c) Producer Statements - Construction Review (PS4) to include relevant monitoring records plus independent NDT/inspection records relating to the building work.
(d) MC to confirm with BCA pre-agreed arrangement for collation and delivery of the above sign off documentation, this being the basis of the BCA's "reasonable grounds" expectation.

APPENDIX C: FIGURE #1 "DROSSBACH DUCT GROUTING UNDERTAKEN IN STAGES"



Explanatory Notes

(1) Purpose of this graphic is to illustrate the proposed 3 stage grouting sequence at Inspection/Monitoring Key Stage PC#5 insofar as it applies to Drossbach ducts.

(2) Refer items 7.1 through 7.5 of the GD2.1(A) "Key Stages of Inspection/Monitoring" paper.

GUIDANCE DOCUMENT 2.1(B)

METHOD STATEMENT FOR DROSSBACH DUCT GROUTING

TECHNICAL PAPER 2.1(B) : METHOD STATEMENT FOR DROSSBACH DUCT GROUTING - DEFAULT PROVISIONS

1.0 INTRODUCTION

1.1 Refer previous document 2.1(A) : 'Quality Assurance – Key Stages of Inspection/Monitoring' which provides context for this paper describing construction stage PC #5 on Drossbach duct splice and base channel grouting.

1.2 The verification of preceding work viz PC #1 thru PC #4 is assumed to have been achieved separately via design engineer's shop drawing sign off, and main contractor's/sub-contractor's inspections of works during construction.

1.3 As written, this method statement excludes activities associated with :

(a) off-site manufacture of the precast concrete wall panel, including the verification that the reinforcing cover to reinforcing steel within the panel exceeds the specified requirements associated with the atmospheric exposure of the exterior surfaces of the wall panel ref PC #1, and PC #2;

(b) Construction of the foundation support system, including the setting out of vertical starter reinforcing to be incorporated in the splice joint ref PC #3

(c) handling and erection by tilting up of the panel onto the foundation, including all necessary temporary propping support to fully stabilise the panel before it is able to be independently supported ref PC #4; and

- these all to be covered by separate method statements included within a Model Standard Specification to be prepared separately.

1.4 Refer also Figure #1 'Drossbach Duct Grouting Undertaken in Stages' attached to the preceding Technical Paper 2.1(A).

2.0 BACKGROUND ASSUMPTIONS

2.1 For the purposes of discussion, this Method Statement is based on the grouting of Drossbach ducts and base channel void under a 6 m long × 2.8 m high × 150 mm thick precast concrete wall panel erected by others onto a pre-constructed foundation.

2.2 Vertical stitching requirement presumes that:-

(a) slab/foundation seating horizontal/roughened along full length of panel;

(b) D20 reinforcing bars located at specified centres/positions projecting a specified 1200 mm up from slab/foundation seating;

(c) centres/positions of Drossbach ducts within the panel have previously been verified as matching slab/foundation D20 starter positions to prescribed tolerance;

(d) panel supported on 4No plastic or stainless steel shims, supplemented by dry pack mortar and/or continuous PVC strips along panel edges and across ends

- all as per the general arrangement shown on Figure #1 previously referenced at item 1.4 above.

2.3 This method statement sets out the grouting sequence required to satisfy the requirements of the structural design as approved via the building consent.

2.4 Focus of this method statement is the site-based activities of the contractor/subcontractor required to ensure compliance in the following activities :

(a) Preparation of the horizontal interface surface junction between the base/lower surface of the precast panel and the supporting foundation/slab which supports it.

NB : The structural design approved via the building consent requires that this bearing surface generates a shear friction factor of not less than 1.0 when evaluated in terms of NZS 3101:2006 clause 7.7.4.

(b) Grouting of the vertical stitch reinforcement splices which crosses the horizontal bearing surface as prepared in accordance with (a).

(c) Achievement of dependable performance in tension, compression and shear in the finished construction of the interface joint that is consistent with that expected within structural elements of this type.

3.0 DEFAULT GROUTING SEQUENCE

3.1 Once panel has been set in place, grouting of reinforcing bar into the Drossbach ducts will be carried out using the following 2 stage grouting sequence.

(a) Stage 1

First lift, being a bedding layer poured under gravity through the bottom grouting port to a line at 25 mm above the underside of the precast panel along its full length.

NB : On completion of Stage 1, it is recommended that the installer "air pressure test" a sample (say 25%) of the Drossbach ducts to ensure that there is no potential for leakage of grout beyond the Stage 1 surface.

(b) Stage 2

Second lift, being with each individual duct from the Stage 1 bedding surface over the full height of the Drossbach duct (say 700 mm) up to within 25 mm of the top grouting port.

NB : Grout used for this lift is normal specification and, because there is no cross-linkage along the longitudinal base cavity, this is carried out individually for each duct.

(c) For avoidance of doubt, the Stage 2 grouting process anticipates that grout will, in all cases, be installed under pressure from the bottom grouting port until grout material exudes from the top part.

NB : Grouting downwards from the top port is not acceptable process under Stage 2 via this default procedure.

(d) Refer to the attached graphic showing the limits of Stage 1 and Stage 2 grouting.

3.2 At the end of each stage, the grouting subcontractor shall inspect the grout surface at representative locations to confirm that the top surface is :

(a) at Stage 1, not less than 25 mm above base of panel and at the level specified; and

(b) at Stage 2, being within 25 mm of the top grouting port for vertical ducts.

3.3 Stage 3 will involve grouting (using low strength grout) or injection using sand/cement mortar to fill the top void section remaining in the duct.

NB : In normal circumstances, the top grouting port will be plastered flush on completion of Stage 2 grouting.

4.0 CONSTRUCTION MONITORING

4.1 Grouting subcontractor will provide the engineer responsible for monitoring the works reasonable opportunity to :

(a) review/comment on the subcontractor's method statement for the grouting works;

(b) observe grouting and stroboscopic inspection on completion of grouting as the grouting operations are undertaken; and

(c) the results obtained (and reported on) at the completion of each grouting stage.

4.2 The grouting subcontractor needs to provide all QA inspection equipment referred to in this method statement - refer item 5 following.

4.3 Refer previous Technical Paper 2.1(A) : "Key Stages of Inspection/Monitoring" for separate discussion on this topic.

5.0 QA INSPECTION EQUIPMENT

5.1 Grouting subcontractors following this specification must undertake their own quality assurance for the 2 stage grouting operation as described above using either :

(a) proprietary strobe-scope, eg Visi-strobe or equal, incorporating a tube of suitable length whose observing tip has full articulation capability, including :

(i) visibility cone of 120° from the tip; and
(ii) ability to provide video/photo record; or

(b) an equivalent instrument with similar attributes.

5.2 The grouting subcontractor needs to produce a written report for the engineer to back his Producer Statement - Construction (PS3) which attests to the grouting having been installed as specified.

6.0 SUPPLEMENTARY INSPECTION CHECKS

6.1 Prior to erection of panel (by others), the main contractor and/or grouting subcontractor needs to undertake a survey to record the surface roughness of the bottom of the panel and the foundation and/or floor slab "contact zone" which supports the precast panel, which should delineate :

(a) surface roughness amplitude contributing to shear friction (with photographs); and

(b) removal of contaminants to the bearing surface, eg laitance, that might if left de-rate the shear friction available within the contact zone.

6.2 Prior to grouting, the main contractor and/or grouting subcontractor needs to undertake a survey of cover to reinforcing in two areas as cast.

(a) Panel surfaces exposed externally, eg category B1 or B2.

(b) Panel surfaces exposed internally, eg Category A1.

7.0 ATTACHMENTS

Refer Figure 1 "Drossbach Duct Grouting undertaken in Stages".

GUIDANCE DOCUMENT 2.1(C)

METHOD STATEMENT FOR PROPRIETARY COUPLER/GROUT SLEEVES GROUTING

TECHNICAL PAPER 2.1(C) : METHOD STATEMENT FOR PROPRIETARY COUPLER/SLEEVE GROUTING - DEFAULT PROVISIONS

1.0 INTRODUCTION

1.1 Refer previous document 2.1(a) : 'Quality Assurance – Key Stages of Inspection/Monitoring' document which provides context for this paper describing construction stage PC #5 on reinforcing splice duct and base channel grouting.

1.2 The verification of preceding work viz PC #1 thru PC #4 is assumed to have been achieved separately via the design engineer's shop drawing sign off, and main contractor's/sub-contractor's inspections of works during construction.

1.3 As written, this method statement excludes activities associated with :

(a) off-site manufacture of the precast concrete wall panel, including the verification that the reinforcing cover to reinforcing steel within the panel exceeds the specified requirements associated with the atmospheric exposure of the exterior surfaces of the wall panel ref PC #1, and PC #2;

(b) Construction of the foundation support system, including the setting out of vertical starter reinforcing to be incorporated in the splice joint ref PC #3; and

(c) handling and erection by crane lifting of the panel onto the foundation, including all necessary temporary propping support to fully stabilise the panel before it is able to be independently supported ref PC #4

- on the basis that these all are to be covered by separate method statements included within a Model Standard Specification to be prepared separately.

1.4 Refer to grout sleeve manufacturer for specification drawings and diagrams of grout sleeves, shims, threaded bars, threaded bar installation into grout sleeve, base grout retainment method, roughness of panel and base surfaces, and the grouting process itself.

2.0 BACKGROUND ASSUMPTIONS

2.1 For the purposes of discussion, this Method Statement is based on the grouting of grout sleeves and base channel void under a 6 m long × 2.8 m high × 150 mm thick precast concrete wall panel erected by others onto a pre-constructed foundation.

2.2 Vertical stitching requirement presumes that:-

(a) slab/foundation seating horizontal/roughened along full length of panel;

(b) D20 reinforcing bars located at specified centres/positions projecting a specified height of 250 mm up from slab/foundation seating;

(c) centres/positions of Drossbach ducts have previously been verified as matching D20 starter positions to prescribed tolerance;

(d) panel supported on 2No plastic shims, supplemented by dry pack mortar and/or continuous PVC strips along panel edges and across ends

- all as per the general arrangement shown on manufacturer's drawings and diagrams.

2.3 This method statement sets out the grouting sequence required to satisfy the requirements of the structural design approved via the building consent.

2.4 Focus of this method statement is the site-based activities of the contractor/subcontractor required to ensure compliance of the following operations :

(a) Preparation of the horizontal interface surface junction between the base/lower surface of the precast panel and the supporting foundation/slab which supports it.

NB : The structural design approved via the building consent requires that this bearing surface generates a shear friction factor of not less than 1.0 when evaluated in terms of NZS 3101:2006 clause 7.7.4. This requires a surface roughness with a 2 mm amplitude.

(b) Grouting of the vertical stitch reinforcement splices which cross the horizontal bearing surface as prepared in accordance with (a).

(c) Achievement of dependable performance in tension, compression and shear in the finished construction of the interface construction joint that is consistent with that expected within structural elements of this type located.

3.0 DEFAULT GROUTING SEQUENCE

3.1 Once panel has been set in place, grouting of reinforcing bar into the grout sleeves will be carried out using the following 2 stage grouting sequence.

(a) Stage 1

First lift, being a bedding layer pumped through grout tubes along the base until there is a head of grout observed in the next grout tube of 20 mm. Plug the tube and restart base grouting at next tube until the base is fully grouted.

NB : On completion of Stage 1, it is recommended that the installer "air pressure test" a sample (say 25%) of the grout sleeves to ensure that there is no potential for leakage of grout beyond the Stage 1 surface.

(b) Stage 2

Second lift, being with each individual sleeve from the Stage 1 bedding surface over the full height of the grout sleeve - up to 20 mm above the top of the grout sleeve capacity by observing the turned up top grout tube. Seal top tube. Remove pump and immediately plug the grouting tube.

NB : Grout used for this lift is normal specification and, because there is no cross-linkage along the longitudinal base cavity, this is carried out individually for each sleeve.

(c) For avoidance of doubt, the Stage 2 grouting involves installation from the bottom grouting port (upward grout flow under pressure head).

3.2 At the end of each stage, the grouting subcontractor shall inspect the grout surface at representative locations to confirm that the top surface is :

(a) at Stage 1, 5-15 mm above base of panel; and

(b) at Stage 2, not less than 20 mm above the top of the grout sleeve cavity.

NB : In normal circumstances, grouting ports will be plastered flush on completion of grouting.

4.0 CONSTRUCTION MONITORING

4.1 Grouting subcontractor will provide the engineer responsible for monitoring the works reasonable opportunity to :

(a) review/comment on the subcontractor's method statement for the grouting works;

(b) observe pre-grout inspection of sleeves and grouting as the grouting operations are undertaken; and

(c) the results obtained (and reported on) at the completion of each grouting stage.

4.2 The grouting subcontractor needs to provide all QA inspection equipment referred to in this method statement - refer item 5 following.

4.3 Refer previous guidance document 2.1(a) : "Key Stages of Inspection/Monitoring" for separate discussion on this topic.

5.0 QA INSPECTION EQUIPMENT

5.1 Grouting subcontractors following this specification must undertake their own quality assurance for the 2 stage grouting operation as described above using either :

(a) proprietary strobe-scope, eg Visi-strobe or equal, incorporating a tube of suitable length whose observing tip has full articulation capability, including :

(i) visibility cone of 120° from the tip; and
(ii) ability to provide video/photo record; or

(b) an equivalent instrument with similar attributes

- with particular emphasis on providing reliable assurance that the proprietary grout sleeve is in fact 100% filled with grout.

5.2 The grouting subcontractor needs to produce a written report for the engineer to back his Producer Statement - Construction (PS3) which attests to the grouting having been installed as specified.

6.0 SUPPLEMENTARY INSPECTION CHECKS

6.1 Prior to erection of panel (by other), the main contractor and/or grouting subcontractor needs to undertake a survey to record the surface roughness of the bottom of the panel and the foundation and/or floor slab "contact zone" which supports the precast panel, which should delineate :

(a) surface roughness amplitude contributing to shear friction (with photographs); and

(b) removal of contaminants to the bearing surface, eg laitance, that might if left de-rate the shear friction available within the contact zone.

6.2 Prior to grouting, the main contractor and/or grouting subcontractor needs to undertake a survey of cover to reinforcing in two areas as cast.

(a) Panel surfaces exposed externally, eg category B1 or B2.

(b) Panel surfaces exposed internally, eg Category A.

7.0 ATTACHMENTS

Refer Grout Sleeve manufacturer's standard details, drawings, and diagrams of grouting.

GUIDANCE DOCUMENT 2.1(D)

COVER TO REINFORCEMENT - VERIFICATION METHODOLOGY

TECHNICAL PAPER 2.1(D) : COVER TO REINFORCEMENT - VERIFICATION METHODOLOGY

1.0 INTRODUCTION

1.1 Specifying the installation of Drossbach ducts/grout sleeves with precast wall panels requires consideration of several factors.

(a) Positioning the ducts/sleeves accurately **along the length** of the wall to ensure that the projecting reinforcing starters "mate" (or align) with the Drossbach/sleeve voids.

(b) Positioning of ducts accurately within the **through thickness** of the wall panel to achieve :

(i) sufficient cover typically to horizontal reinforcing on external wall face - ie the face exposed to weather, eg 40 mm; and
(ii) sufficient cover to horizontal reinforcing on interior face, eg typically 25 mm.

(c) Ensuring that inspections undertaken by the precaster target those zones which are vulnerable to short cover.

1.2 The focus of this paper is primarily on (b) and (c) above - ie the avoidance of "short cover to reinforcing" defects in the finished wall panel construction.

2.0 POSITIONING OF DROSSBACHS/GROUT SLEEVES

2.1 As noted in the separate paper on monitoring/inspection obligations, it is important that standard positioning details for Drossbach ducts/grout sleeves within the walls recognise that in the general case for external walls the Drossbach ducts/grout sleeves may be positioned offset to the wall centreline.

NB : Vertical reinforcement, where not central in the panel, affects its strength and out-of-plane stiffness. These effects must be calculated where vertical reinforcement is not placed central in the panel, and accordingly the positioning of vertical reinforcing in this manner will require formal sign-off by the design engineer at shop drawing approval stage.

2.2 As discussed separately in DG#3 "Design Basis" guidance, grouting methodology for Drossbach ducts assumes that the internal duct diameter is not less than three times the normal diameter of the reinforcing bar to be spliced.

2.3 We include as figures in Appendix A to this paper some graphics relating to an NZS 3101:2006 section 3 (Durability) compliant installation.

(a) Figure 2 showing cover dimensions and check measurements (including related tolerances) as applied to precast wall panels intended for use in external wall panels.

(b) We note that covers specified in NZS 3109:1997 cl 5.3 give minimum clear cover dimensions to reinforcing that are absolute values and not able to be reduced by tolerances.

NB : This statement within NZS 3109:1997 cl 5.3 requires Note 2 appended to Table 5.2 to be applied also to Table 5.1, which in our view is a reasonable interpretation of performance requirement inherent in this standard.

(c) Ultimately, these factors will govern the positioning of the Drossbach ducts/grout sleeves within the precast panel edge forms.

3.0 METHODOLOGY - NEWLY CONSTRUCTED WALL PANELS

3.1 Whilst visual observations of Drossbach ducts/grout sleeves and other embedments within the precast concrete wall panel forms should be sufficient to identify instances where short covers might exist ahead of the concrete placement, this should not be the only check.

3.2 It is therefore important that both the panel manufacturer and the main contractor keep in mind the following "quality control" options -

(a) Undertaking non-destructive reinforcing cover measurements on representative samples of the completed wall panel using either ferroscan (magnetic) "GPR" or ultrasonic inspection equipment as a practical means of achieving this.

(a) Verifying in particular the minimum clear cover measured at key locations within the panel which have been identified as potential "non-compliance zones".

4.0 METHODOLOGY - EXISTING WALL PANELS

4.1 For existing panels, the objective is to identify the extent of short cover existing in the panels and possible approaches to remediating the problem. In such cases, summarising ferroscan results on a "Manhattan" style graphic similar to that shown in Appendix A is a preferred reporting approach because :

(a) where the specified minimum clear cover limit is specified, the number of bars or grout sleeves (if any) within that zone is identified; and

(b) where such non-compliances are found to exist, the number (and percentile distribution) of reinforcing bars located within the prescribed cover zone can be identified and evaluated in a statistical sense.

NB : Refer "Neville" probability distribution which records key parameters for both horizontal and vertical D20 reinforcing bars with a typical 200 mm thick precast wall panel installed with Drossbach ducts in a representative 20 year old multi-unit apartment building located in Auckland.

4.2 FTL's project experience in such surveys is that ferroscan surveys intending to present results in this manner require appropriate specification at the time the work is scoped as it requires use of special equipment, eg ferroscan PS200 (or equal) equipment, alongside conventional GPR scans as results obtained may be obscured by the crossover of reinforcing.

5.0 QUALITY ASSURANCE

5.1 It is recommended that the quality assurance programme deliberately aims to address the above "short cover" issues at the following inspection stages :

(a) Stage PC #1 : Shop Drawing Review;

(b) Stage PC #2 : Precast Panel Construction; and

(c) Stage PC #6 : Monitoring Sign Off.

NB : "PC" references are described in paper 2.1(a) QA - Key Stages of Inspection/Monitoring included separately within Part A of this guideline.

APPENDICES

E Extracts from NZS 3109:1997 section 5.3 Tolerances

F Figure 2 : FTL sketch 46275/CVR/01(A)

GUIDANCE DOCUMENT 2.1(E)

PROCUREMENT SPECIFICATION OUTLINE - KEY HEADINGS

TECHNICAL PAPER 2.1(E) : PROCUREMENT SPECIFICATION OUTLINE - KEY HEADINGS

1.0 INTRODUCTION

1.1 As noted in previous sections, the purpose of the engineer's specification is to provide the main contractor with the storehouse of design and assurance information essential for informing :

(a) the manufacture of the precast concrete component, eg wall panel;

(b) its transport, erection, and installation (including connection grouting); plus

(c) the quality assurance framework which will be applied to both.

1.2 It is not the function of this part of the guidance to recommend a particular specification wording, although, it does include particular "model clause" recommendations relating to recognised "problem areas" that we recommend be specifically addressed by the design engineer in the particular specification for precast concrete rather than defaulting to the general concrete construction specification.

2.0 ASSUMPTIONS

2.1 It is assumed that a suite of inter-related "Materials and Workmanship" specifications will operate for structural concrete on the project in behind that dedicated to "Precast Concrete", viz :

(a) Concrete - General;

(b) Reinforcing Steel;

(c) Structural Steelwork; and

(d) Other similar trends.

2.2 It is assumed that the dedicated "Precast Concrete" specification will cover :

(a) precast concrete - component manufacture and supply; and

(b) precast concrete - transport, erection, and installation (including grouting of splice connections).

2.3 Further, it is assumed that the manufacturer, viz precaster, and main contractor (including subtrades supplying it) will have in place a system of pre-pour/inspection/check lists which will operate for each stage of the manufacturing process as part of the wider quality assurance framework.

3.0 MODEL CLAUSES FOR SPECIFICATION

3.1 Model specification clauses (or "bullet point" outlines for the design engineer's development of such clauses) are included at item 4.0 for :

(a) quality assurance framework for precast supply, manufacture, and installation as a complete package;

(b) grouting of Drossbach ducts/grout sleeves into precast concrete components; and

(c) shop drawings - obligation to prepare and complete an accurate description of each component and submit manufacturing drawings for approval by design engineer.

3.2 "Quality Assurance" framework for particular specification for precast concrete components should cover the following :

3.2.1 General - control of manufacture

3.2.2 QA coverage for precast concrete components

(a) Formwork

(b) Reinforcing steel

(c) Embedments

(d) Concrete quality

(e) Concrete finishes

(f) Tolerances

(g) Transport

(h) Installation

3.2.3 Representative supplier information to be supplied with tender

(a) Agreed format for check lists

(b) Inspection (including completion of check lists) prior to casting

(c) Sourcing certificates and records for materials supplied

(d) Name of material suppliers, eg concrete, reinforcing, embedments

(e) Name and qualifications of specialist subcontractors, eg grouting subcontractor

3.2.4 Records availability for review/audit by engineer

3.2.5 Acceptance/Acknowledgement of construction review obligation

(a) General requirements ref NZS 3109:1997 clause 1.3

(b) Key stages for inspection/monitoring identified for sign off purposes

(i) Stage PC#1 : Panel shop drawing review
(ii) Stage PC#2 : Panel pre-construction inspection
(iii) Stage PC#3 : Foundation/slab projecting starter set out review
(iv) Stage PC#4 : Panel handling/erection/stability/alignment inspection
(v) Stage PC#5 : Grouting of base channel and vertical Drossbach ducts/grout sleeves

(c) Quality assurance sign offs for PC#1 through PC#5 above, including provision of Producer Statement - Construction (PS3)

3.2.6 Certification of precast units as manufactured/installed with back-reference to :

(a) shop drawings; and

(b) specification.

3.3 Model Clauses : Grouting of Drossbach Duct/Grout Sleeve Splices in Precast Components

3.3.1 Model clause : casting of Drossbach ducts and/or grout sleeves into precast components etc

Where noted on the drawings, corrugated metal formers, eg proprietary "Drossbachs" or "Uniflex" ducts, shall be used to form voids to accommodate grouted splice connections for projecting reinforcing. Alternatively, where noted in the drawings, proprietary grout sleeves shall be used to form voids to accommodate grouted splice connections or projecting reinforcing subject to the installation complying with the written requirements of the manufacturer. Use of alternative formers, eg plastic ducts, shall not be permitted as a substitute for metal.

Polyethylene (or similar) tubes will be incorporated into the Drossbach duct assembly to connect into base and top of the Drossbach duct from the outside of the precast panel and be used by grouting subcontractor for grouting the site splice connections. The exposed ends of grout tubes shall be recessed into exposed concrete surfaces on completion.

Recognise that close tolerances are required to be achieved in positioning the Drossbach ducts/grout sleeves within the panel in order to avoid :

(a) reduction to specified cover to horizontal or stirrup reinforcing passing around the ducts; and

(b) ducts/sleeves becoming "out of register" with vertical starter reinforcing from below or to above.

Ensure grouting system is fully sealed along the base so that concrete cannot flow into vertical ducts/grout sleeves or grout tubes during the casting of the panel. Undertake checks by air pressure testing or other approved means that this requirement is achieved.

3.3.2 Model clause : wall panel seatings and pre-grouting sealing

Pre-level plastic shim plates on top of the concrete foundation or floor slab ready to receive and support the panels.

Seal the joint at the base of the panels and grout the joint and the starter bar ducts with high-strength grout.

Undertake air pressure (or similar) tests at each step to verify that base channel and vertical ducts are fully sealed against leakage prior to installing grout.

3.3.3 Model clause : grouting of Drossbach ducts/grout sleeves in precast components

All ducts/sleeves and associated gaps forming the interface between adjacent concrete components, where noted on the drawings, shall be grouted with proprietary non-shrink high-strength grout or approved equivalent.

Grouting shall be carried out from "bottom up" so that air is expelled as grouting continues, and all voids between concrete units in Drossbach ducts/grout sleeves are completely grout filled. The grout shall be mixed and placed in strict accordance with the manufacturer's instructions, and tested in accordance with requirements specified separately.

The contractor shall nominate the persons responsible for quality assurance of mixing and placing the grout.

A testing programme shall be agreed between the grout manufacturer and the engineer at the commencement of the works which shall then be followed throughout the job. The tests shall demonstrate that the grout as placed :

(a) has a minimum strength of 40 MPa* minimum at seven days and 60 MPa* minimum at 28 days;

(b) flows to entirely cover the concrete/concrete joint interface;

(c) does not bleed mix water to create voids at this interface;

(d) does not shrink; and

(e) does not incorporate air pockets or voids of any type or size.

Clean off any spillage or leakage immediately after the completion of grouting.

NB : The specified grout strengths are equivalent to cylinder crushing strengths (being 80% of the corresponding cube strength values).

3.3.4 Model clause : void-free grout infill verification

(a) Grouting of connections in precast concrete components shall be undertaken only by an appropriately trained and qualified specialist subcontractor with experience in this type of work.

(b) The grouting subcontractor shall provide to the Engineer at time of tender:-

A project specific grouting plan addressing the requirements of this specification which incorporates a quality plan which :

(i) nominates proprietary grout proposed for use on the project;
(ii) lists minimum testing requirements proposed for strength, and workability of the grout;
(iii) lists methods by which preformed voids will be verified as having been effectively sealed before grouting commences; and
(iv) lists methods by which the 'grouting infill process' for all preformed channels, tubes and other spaces within the hardened precast concrete component (and its supports) will be verified as being void-free on completion.

(c) With regard to item (b)(iv) above, the grouting subcontractor's quality plan must describe the verification process/methodology intended to be used, selected from the following pre-qualified list :

(i) Grout volume calculation ('actual' vs ' predicted') per space to be infilled – default 100% coverage
(ii) Destructive sampling eg post-grouting drilling of sample of base channels and/or grout tubes – default minimum frequency 5%
(iii) Non-destructive sampling eg ultra-sound or X-ray survey of base channels and/or grout tubes (including detection of reinforcing steel) – default minimum frequency 10%

3.4 Shop Drawing Requirements

3.4.1 Shop drawings shall be provided to describe essential requirements for :

(a) manufacture of precast component, including the concrete plus all reinforcing steel, embedments etc required by the design to be incorporated;

(b) set out requirements for any abutting connections, eg foundation reinforcing starters;

(c) set out requirements to ensure specified cover to reinforcement is achieved (including tolerances);

(d) locations and fixing of Drossbach ducts/grout sleeves (including grouting tubes) (including tolerances); and

(e) includes unique identifier references for the panel.

3.4.2 Shop drawings shall be submitted by main contractor/precaster to design engineer 14 days prior to schedule date of manufacture for confirmation that contractor has correctly interpreted engineer's design, plus all other associated requirements.

3.4.3 Precaster to certify that precast concrete components as manufactured comply with plans and specifications (and the approved shop drawings).

4.0 PRE-CONSTRUCTION DIALOGUE – MEETINGS BETWEEN DESIGN ENGINEER AND MAIN CONTRACTOR/SUBCONTRACTORS

4.1 Introduction

4.1.1 Key stages for inspection/monitoring have been identified ref PC#1 through PC#5 for sign off purposes.

4.1.2 This section of the specification sets out recommendations as to how the design engineer might implement the specified quality assurance measures using stage-specific meetings on the project.

4.1.3 These meetings comprise :

(a) pre-construction meeting #1 with precast panel supplier;

(b) pre-erection meeting(s) No.2 with main contractor/subcontractor; and

(c) pre-construction meeting #3 with grouting subcontractor.

NB : Frequency of meetings specified in this section are indicative, and may well apply only to the initial phases of construction or when recorded non-compliances start to occur in the finished works.

4.2 Pre-construction meeting #1 : Precast Panel Supplier (PC#1, PC#2)

4.2.1 Scope - stage PC#1 (shop drawing review) and PC#2 (pre-construction inspections)

4.2.2 Attendees : Design Engineer
Main Contractor
Precast Sub-contractor
Supplier Representative

4.2.3 Venue : Precaster's factory

4.2.4 Model Agenda

(a) DE expectation ref manufacturer's programme and associated QA for construction/inspection/sign off stages PC#1 through PC#5 :

(i) Materials and Workmanship Specification - confirmation of understanding of requirements, including those of companion specifications.
(ii) Panel manufacturing process, eg handling transport and erection.
(iii) Panel manufacturer's feedback on "buildability" issues.
(iv) Materials QA verification, eg reinforcing steel, concrete, grout (particularly early age strength).
(v) Achieving dimensional tolerances.
(vi) Embedments, eg weld plates, Drossbach tubes/grout sleeves.
(vii) Specific (primary and secondary reference) docs companion spec.
(viii) Manufacturing programme timeline.

(b) DE expectation for shop drawings (plus associated documents) ref PC#1

(i) Review of shop drawing samples to confirm extent of detail required by DE.
(ii) Preparation and sign off timeline.
(iii) Supplementary information, eg :
- "starter running dimension" sheet (or template) for settlement reinforcing starter/vertical splices
- "lifting eye" location plus panel handing structural calculations
- precaster pre-pour inspection sheets - review/approval

(c) DE expectation for pre-construction panel inspection ref PC#2

(i) Frequency of inspection, and prior notice period required
(ii) Pre-pour inspection sheet completed/verified
(iii) Concrete, reinforcing supply product - information
(iv) Pre-pour tolerance checks for :
- cover to reinforcing steel horizontal bars and/or stirrups over Drossbach (check interior/exterior faces), cover to grout sleeves
- position of grouting duct/sleeve centrelines along and across the panel
- sufficiency/rigidity of grout duct/sleeve (and grout delivery time) fixing within the forms

NB : Precaster's inspection check sheets must include "check boxes" for each of the above tolerance items.

(v) Surface roughness amplitude check to underside base (underside/bearing surface), top (bearing surface), and/or face/surface (dowelled) connections
(vi) Lifting eyes position and erection procedures based on early age testing for representative concrete supply samples

NB : Concrete 28 day crushing strength proposed for use by precaster achieve the 20 MPa threshold required for handling to be submitted for approval as part of PC#1.

(vii) Agreement on post-construction and pre-delivery inspection and sign offs with regard to :
- achievement of minimum clear cover to reinforcement (using ferro scan or similar equipment); and
- achievement of blockage-free and adequately interconnected grouting tubes (using air pressure testing or similar).

4.3 Pre-construction meeting No.2 : Panel support surfaces and starter set out - ref PC#3

4.3.1 Scope - Stage PC#3 (foundation-projecting starter set out)

4.3.2 Attendees : Design Engineer
Main Contractor

4.3.3 Venue : Building site

4.3.4 Model Agenda

(a) DE expectation ref QA verification for projecting starter set out, eg " starter running dimension" sheet and/or template.

(b) Materials and workmanship specification - confirmation of understanding of requirements.

(c) Achieving dimensional tolerances - horizontal (along/across) and vertical (up/down).

(d) Achieving special finishes on panel support surface, eg surface roughness amplitude (plus remedials if required).

4.4 Pre-erection construction meeting No.3 : Panel transport/erection/alignment inspection ref PC#4

4.4.1 Scope - Stage PC#4 (erection/stability, reinforcing splices ready for grouting)

4.4.2 Attendees : Design Engineer
Main Contractor
Panel Erection Sub-contractor

4.4.3 Venue : Precaster's factory and/or building site

4.4.4 Model Agenda

(a) DE expectation ref manufacturer's transport and erection programme using specialist panel erection subcontractors.

(b) Include for post-delivery/pre-erection inspection of panels to site and/or formal acceptance of panels as delivered.

(c) Agree protocols for rejection of damaged panels and remediation to damaged panels, including recording of damage when present.

(d) Confirm tolerances for :

(i) panel placement/vertical and horizontal alignment; and
(ii) junctions with support surface (including sign offs for roughness amplitude that surface).

(e) Confirm nature and materials to be used for vertical support of panels in temporary condition prior to grouting (ref PC#5 to follow).

NB : Proprietary hard plastic shims shall be used for this purpose, and use of steel shims will not be permitted.

(f) Confirm that alignment/fit up of mating parts, viz projecting starters and vertical grout tubes, has been achieved prior to the lifting of panel.

NB : When alignment/fit up is not achieved, dismount the panel and have main contractor record proposal for remedial work to the panel and/or support structure for approval of DE ahead of implementation.

4.5 Pre-construction meeting No.4 : Post-erection/pre-grouting inspection ref PC#5

4.5.1 Scope - Stage PC#5 : Grouting of base channel and vertical reinforcing splices

4.5.2 Attendees : Design Engineer
Main Contractor
Grouting Subcontractor

4.5.3 Venue : Building site

4.5.4 Model Agenda

(a) DE expectation ref granting subcontractors presentation of method statement for work as specified and associated QA processes for review.

(b) Granting subcontractor's confirmation of method statement and associated QA process proposed.

NB : This to be documented.

(c) Method statement to differentiate grouting procedures for :

(i) flat joints; and
(ii) stepped (or ship-lapped) joints

- plus associated construction/grouting and QA procedure for each of these.

(d) Key requirements from specification

(i) Grout strength/flow testing requirements
- 1No test cube required per 150 kg grout mix
- Achieved minimum grout strength 40 MPa at 7 days

(ii) Verification of Void-free grout installation
- Nature of verification tests to be used for absence of voids required for 10% of tubes filled with grout

NB : Specification "General" includes requirement for contractor to positively verify that grout tubes are filled, and requires contractor to propose a method for achieving this by survey sample of not less than 10% - refer model specification clause

(iii) Grout installation method : requirements for grouting subcontractor to verify that :
- base channel and vertical grouting tubes and effectively sealed prior to commencement of grouting, using air pressure test or similar methods
- grout infilling sequence to proceeds "bottom up" in a manner that minimises the requirement for grout to flow horizontally within the base channel void

NB : A 2-stage grouting procedure as per Guidance Document 2.1(b) is normally required to satisfy this requirement.

(e) PS#3 sign off - provide PS#3 "grouting" to cover the grout installation plus association QA checks in terms of all items within (d) above.

5.0 MODEL SPECIFICATION : SECTION HEADINGS (ref Appendix A)

5.1 Refer Appendix A for model specification section headings.

6.0 NON-DESTRUCTIVE TESTING METHODS (ref Appendix B)

6.1 Refer to Appendix B for technical note "Use of Non-Destructive Testing Methods to assist the Quality Assurance Process for New and Existing Construction" as prepared for the Task Group by Daniel Traeger/Construct Structure Investigations Limited.

7.0 REFERENCES

7.1 General Specification Requirements

7.1.1 NZS 3104: 2003 Specification for concrete production - High grade and special grade

7.1.2 NZS 3109:1997 Concrete construction

7.1.3 NZS 3114:1987 Specification for Concrete Surface Finishes

7.1.4 NZS 3112:1986 Methods of Test of Concrete, comprising:-

(a) NZS 3112.1:1986 Methods of test for concrete - Tests relating to fresh concrete

(b) NZS 3112.2:1986 Methods of test for concrete - Tests relating to the determination of strength of concrete

(c) NZS 3112.3:1986 Methods of test for concrete - Tests on hardened concrete other than for strength

(d) NZS 3112.4:1986 Methods of test for concrete - Tests relating to grout

7.2 Particular Spec Requirements

7.2.1 Design Engineer to insert particular specification requirements into their document.

7.3 Relevant Concrete Industry Standards

7.3.1 PCI publication - Manual for Quality Control for Plants and Production of Structural Precast Concrete Products - MNL-116 (4th Edition) 1999 pp400

7.3.2 PCI publication - Recommended Practice for Erection of Precast Concrete (1985) pp96

7.3.3 National Precast Concrete Association Australia - Understanding Grouted Precast Joints - A guide for engineers and building contractors (2020) pp27

7.3.4 Centre for Advanced Engineering, University of Canterbury - Guidelines for the Use of Structural Precast Concrete in Buildings (1999) - Report of a Study Group of the New Zealand Concrete Society and the New Zealand Society for Earthquake Engineering pp174

TECHNICAL PAPER 2.1(E) : PROCUREMENT SPECIFICATION OUTLINE - KEY HEADINGS

Extract from Reference 3.3 - Natural Precast Concrete Association Australia - Understanding Grouted Precast Joints - A guide for engineers and building contractors (2020)

WARNING : Design practices reported in this publication relate to standard practices in Australia, and accordingly should not be adopted without modification in New Zealand..

1. Background for non-seismic environments
2. Design and Specification
    - 2.1 Typical joint types
        - 2.1.1 Flat joints
        - 2.1.2 Stepped (or ship-lapped) joints
        - 2.1.3 Highly loaded joints
    - 2.2 Joint elements
        - 2.2.1 Grout
        - 2.2.2 Sealants
        - 2.2.3 Dowel and starter bars
        - 2.2.4 Ducts and sleeves
        - 2.2.5 Shims & packers
    - 2.3 Joint reinforcement design considerations
    - 2.4 Grouting methods
        - 2.4.1 Grouting methods: accessible flat joints
        - 2.4.2 Grouting methods: inaccessible flat joints
        - 2.4.3 Grouting methods: stepped joints
3. Construction: Design and Erections Designer Responsibilities
4. Constructions: Erector and Grouting Contractor Responsibilities
5. Aesthetic Considerations
6. Conclusion

APPENDIX A : MODEL SPECIFICATION SECTION HEADING : CONCRETE - PRECAST : SUPPLY AND INSTALLATION

Item	General Requirement	Project/Component-specific Requirement	QA/PC ref
1.	Preliminary		
2.	Scope	Cross-referencing notes Companion specifications : - Concrete general - Reinforcing steel - Structural steelwork - Grouting	
	2.1 Scope of supply		
	2.2 Exclusions		
3.	Related Documents	List of NZ and relevant industry standards related to supply and installation NZS 3109:1997 Understanding Grouted Precast Joints. A Guide for engineers and building contractors. National Precast Association - Australia ?	
4.	Quality Assurance	Coverage includes compliance verification for : - Formwork - Tolerances - Reinforcing steel placement - Cast-in items - Concrete quality and testing - Concrete finishes, including roughness of surfaces to be grouted against - Handling, delivery, erection - Grouting	
	*4.1 General	Include buildability review/confirmation	
	*4.2 Quality assurance certification - structural		
	*4.3 Inspection protocols, eg PC#1 through PC#5	Refer DE-mandated site meeting requirement	
	*4.4 Certification of precast units as installed, eg PC#6		
5.	Shop Drawings		
	5.1 Size/format	Minimum requirements separately specified for : (a) flat joints; and (b) stepped joints.	
	5.2 Drossbach ducts and grout injection tubes - locations, standard details, and ancillaries		
	5.3 Grout sleeves and grout injection tubes - locations, standard details, and ancillaries		
6.	General Materials and Workmanship Requirements for Project		
	6.1 General		
	6.2 Tolerances		
	6.3 Masking		
	6.4 Handling		
	6.5 Delivery programme		
	6.6 Stacking		
	6.7 Repair work		
	6.8 Co-ordination		
	*6.9 Drossbach ducts		
	6.10 Grout sleeves		
7.	Particular Requirements for Specific Components Classified by Type and/or Position within Building		
	7.1 Precast concrete shear wall panels		
	7.1.1 General		
	7.1.2 Mould - parting compound		

Item	General Requirement	Project/Component-specific Requirement	QA/PC ref
	7.1.3 Reinforcement		
	7.1.4 Tubular grouting ducts and how sealed to Drossbachs/grout sleeves and how positioned to inside surface of panel		
	7.1.5 Lifting inserts		
	7.1.6 Tolerances		
	*7.1.7 Cast-in inserts		
	7.1.8 Concreting		
	7.1.9 Handling and Erection		
	7.1.10 Sealing		
	*7.1.11 Wall panel seating and grouting		
	7.1.12 Embedments		
	7.1.13 Mating parts information	Reinforcing starter "running dimension" sheet or template.	
	7.2 Precast concrete façade panels		
	7.2.1 General		
	7.2.2 Mould - parting compound		
	7.2.3 Reinforcement		
	7.2.4 Tubular grouting ducts		
	7.2.5 Lifting inserts		
	7.2.6 Tolerances		
	7.2.7 Cast-in inserts		
	7.2.8 Concreting		
	7.2.9 Handling and Erection		
	7.2.10 Sealing		
	*7.2.11 Wall panel seating and grouting		
	7.2.12 Embedments		
	7.2.13 Mating parts information	Reinforcing starter "running dimension" sheet or template.	

APPENDIX B : USE OF NDT METHODS TO ASSIST QA PROCESS FOR NEW AND EXISTING CONSTRUCTION

Title:- 'Use of Non-Destructive Testing Methods to assist the Quality Assurance process for New and Existing Construction.'
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Date:- 19/10/2021

One feature generally absent from modern construction programs is the utilization of non-destructive testing (NDT) methods in the QA process.

NDT describes a group of analysis techniques used in a wide range of areas and applications. It does not alter the material or structure being inspected, subsequently it is a highly valuable technique that can save both money and time in product evaluation and troubleshooting.

Generally, for concrete NDT methods can evaluate concrete properties, uniformity, honeycombing, segregation, and cover depth as well as detecting buried reinforcement, to name a few.

Some items where NDT methods can add value to the QA process are listed below:

1. Quickly assessing product uniformity in real-time as construction progresses
2. Identifying potential defects during construction to allow for timely corrective measures
3. Enabling more frequent inspection, testing, and replication without the damaging effects of destructive testing
4. Minimising testing and inspection costs, while improving construction quality
5. Providing complimentary information to other methods such as invasive inspections
6. Suitable for using a statistical approach

The above-mentioned items can be applied to the inspection of both Drossbachs and Grout-Sleeves. CSI has specifically developed this application in cooperation with Callaghan Innovation by use of ultrasound technology. It is possible that other (acoustic) techniques may well be suitable for this type of NDT investigation, although this has not been established at this stage.

Some NDT technologies provide the option to display visual images of the results. These must be seen as visual representation only and not be used for analysis. Typically, raw data are used for analysis which are subject to interpretation. Subsequently, analysis of data should only be undertaken by trained, qualified and experienced personnel. This is certainly the case for any wave propagation technology which includes ultrasound.

With ultrasound scanning the entire volume-fill of a grouted connection can be inspected which allows the analyst to pick up localised voiding, other inconsistencies, and areas of low-density grout. In contrast to this, however, invasive inspections using e.g. drilling or excavation provide only a localised spot-check, missing potential areas of concern beyond the point of excavation.

It is also possible to identify the grout-fill level using ultrasound. This approach has the advantage of keeping the inspection cost low and avoiding intrusive works including its subsequent remediation.

NDT is used to best effect when it is combined with other means of inspection and verification methods. It is an option, at the engineer's discretion, that ultrasound (or other NDT methods) is used to inspect only structural

key elements such as columns and shear walls, while other areas designed for a lower load demand can be inspected by drilling and borescope.

Statistical process control is a tool used for quality improvement. A sample size for NDT of 10% is advisable depending on the project size. If irregularities are found a statistical assessment may be helpful to distinguish between a commonly occurring, isolated or 'special cause' in variation. An increase in testing numbers is recommended until the cause is established and corrective measures are implemented.

For the currently used methodology there are differences in what is achievable in identifying defects for the different grout-connection details as follows:

Drossbachs:

- ✓ Empty duct, e.g. no grout fill
- ✓ Grout-fill height confirmation
- ✓ Void detection (voids larger than approx. 20mm)
- ✓ Variations in material properties to some degree (allowing to conclude compromised or probable low density)
- ✓ Confirming the presence or absence of a reinforcing bar (under ideal conditions)
- ✓ Grout volume confirmation (by grouting subcontractor, or other)

Grout-sleeves:

- ✓ Empty sleeve, e.g. no grout fill
- ✓ Presence or absence of grout
  Note that a more detailed quantification is not possible for grout sleeves at the time of writing this paper.

The current recommendation is that testing shall not be undertaken earlier than 7 days from the day of the grout pour. This minimum timeframe is based on the Standard (ASTM and others) for Low Strain Integrity Testing where an acoustic technology is used for evaluation. It is probable that testing Drossbachs and grout-sleeves can be undertaken earlier. The efficacy of this is still to be established.

It is important to include time allowance in a construction program for the requirements of NTD QA measures. Testing must be aligned with the installation of grouted connection details. Any supporting documents shall be provided to the NDT inspector and reasonable access to the test locations must be provided.

The engineer or principal client may consider the quality assurance benefits to the project of using an independent NDT service.

Summary/Conclusions:-

Some advantages to independent testing are as follows:

1. Provides an uninfluenced third-party view, avoiding a conflict of interest
2. Potential to finding more defects
3. Immune from management pressure
4. Access to the best talent and latest technologies
5. Total cost of ownership in acknowledgement of investment, training, certification, and maintenance of high technology equipment and personnel.