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NEW ZEALAND SOCIETY FOR EARTHQUAKE ENGINEERING

Shear wall design tool – Structural Engineering Design Society NZ (SESOC)

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ABSTRACT

SESOC has, over a period of time, developed and acquired a number of structural software design programs.

This paper will preview a new development, namely "Gen-Wall", a software program developed specifically for the design of reinforced concrete (RC) shear walls to NZS 3101.

It also briefly overviews the other SESOC software, including the recently launched MemDes+ software.

1 INTRODUCTION

1.1 Software Origins

It was by happenstance, back in the early - mid 1990s, that SESOC became involved in software, as a result of the considerable enthusiasm of one of our early members, Esli Forrest. He initially developed the Soils program, later followed by the BeamDes program. Further detail is provided in the SESOC Software Overview [1] paper presented by the present author to the 2017 SESOC Conference.

Circa 2012, due to failing health, Esli relinquished responsibility for the SESOC software. We are deeply indebted to his early contribution to SESOC.

Some years later, Pacific Steel approached SESOC with the request to take over Gen-Col and its ongoing support, subsequently launched in October 2014 under the SESOC moniker.

In 2017, following discussions with New Zealand Steel / Steltech, SESOC further took on responsibility for MemDes, a segment-based steel design software program. This was later enhanced with a separate module, a member-based program, MemDes+.

In a further development, SESOC has now developed Gen-Wall – the primary focus of this paper.

2 SOFTWARE PHILOSOPHY, DISCLAIMER, & ACCESS

2.1 Software Philosophy

For clarity, the reader should be aware that SESOC is not in the business of providing software per se, but rather it is in the business of providing value to its members - of which software is a part. Clearly, as informed by the software usage statistics, our members are valuing the software aspect as a significant part of the SESOC membership package & benefits.

As a further point of clarification, SESOC is not interested in competing with any commercial software, nor involvement where software is available from other sources. Nevertheless, it was evident that with the small size of the NZ market, and the relative uniqueness of our design standards, there are some opportunities for "simple" and "niche" software programs. One of the key criteria was, and is, to benefit a significant proportion of our members, especially the consultancies at the smaller end of the spectrum who may not have the resources or skills for in-house development.

On a related note, in terms of software philosophy, the reader will be aware that SESOC membership is to individuals only, rather than companies. This was an intentional and conscious decision from the inception of the organisation – and which is equally applicable to the software itself, i.e. software is made available to individual members only.

2.2 Software Access, Licensing, & Support

All SESOC software is available from the members area of the SESOC website.

The software is available to financial SESOC members only, and utilises a third-party software registration system to manage software use. This involves registration on the users' PC via a Software Registration Key (SRK). The SRK is unique to each member, and is currently available under the user's login on the Engineering New Zealand website, with detailed instructions also available on the SESOC website.

Software support is provided via email, software@sesoc.org.nz, provided by Maxx Information Systems. This support is primarily intended for software and registration issues, rather than technical.

2.3 Software Disclaimer

Users are specifically directed to the disclaimer on each program, and to use the software appropriately. In particular, the software is not intended for design circumstances beyond the users' competency, or where they would not be able to independently undertake hand calcs for verification or other purposes.

3 GEN-WALL

3.1 Background

While software is currently available which carries out 'broad' shear wall design, e.g. flexure and axial, there is no commercially available software which addresses the specific design provisions of the NZ Concrete Standard NZS 3101. Further, anecdotally, there are few, if any, consultancies which have a robust in-house program to address these aspects.

As RC shear walls are an integral and key part of a large number of New Zealand buildings, it is important that these are designed and detailed correctly.

Further, due to the multitude and complexity of the NZS 3101 structural wall shear, confinement, and ductility provisions, it is postulated that properly implemented software is the only option – hand

calculations being prohibitively time consuming, and hence commercially untenable, for all but the simplest shear walls.

For these reasons – and the benefit of our members, SESOC has embarked on the development of this software.

3.2 Scope

In broad terms, the proposed scope of work includes:

- Development of a bespoke RC shear wall design program
  - with sectional based design checks
  - . . . and which builds upon the analysis/capacity capabilities of Gen-Col
- Reinforcing design and detailing capabilities, including
  - Flexure, shear, and confinement
  - . . . to NZS 3101, including ductility provisions
  - Singly and doubly reinforced
- Geometry-wise, the program currently covers the following section shapes:
  - Rectangular
  - Rectangular with enlarged boundary element at each end
  - Rectangular with end flanges
- Ductility-wise, the program covers nominally ductile, limited ductile, & fully ductile
- Graphical representation of the input geometry and rebar layout
- Gen-Wall is a standalone, interactive design tool

3.3 Implementation

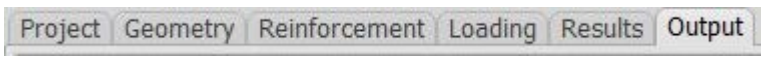
Gen-Wall has been implemented in a tabular interface format, similar to MemDes and the more recent MemDes+.

Significant effort has been expended to make the program as simple and intuitive as possible. Further, graphical representation provides immediate visual feedback on the designers' input, where possible.

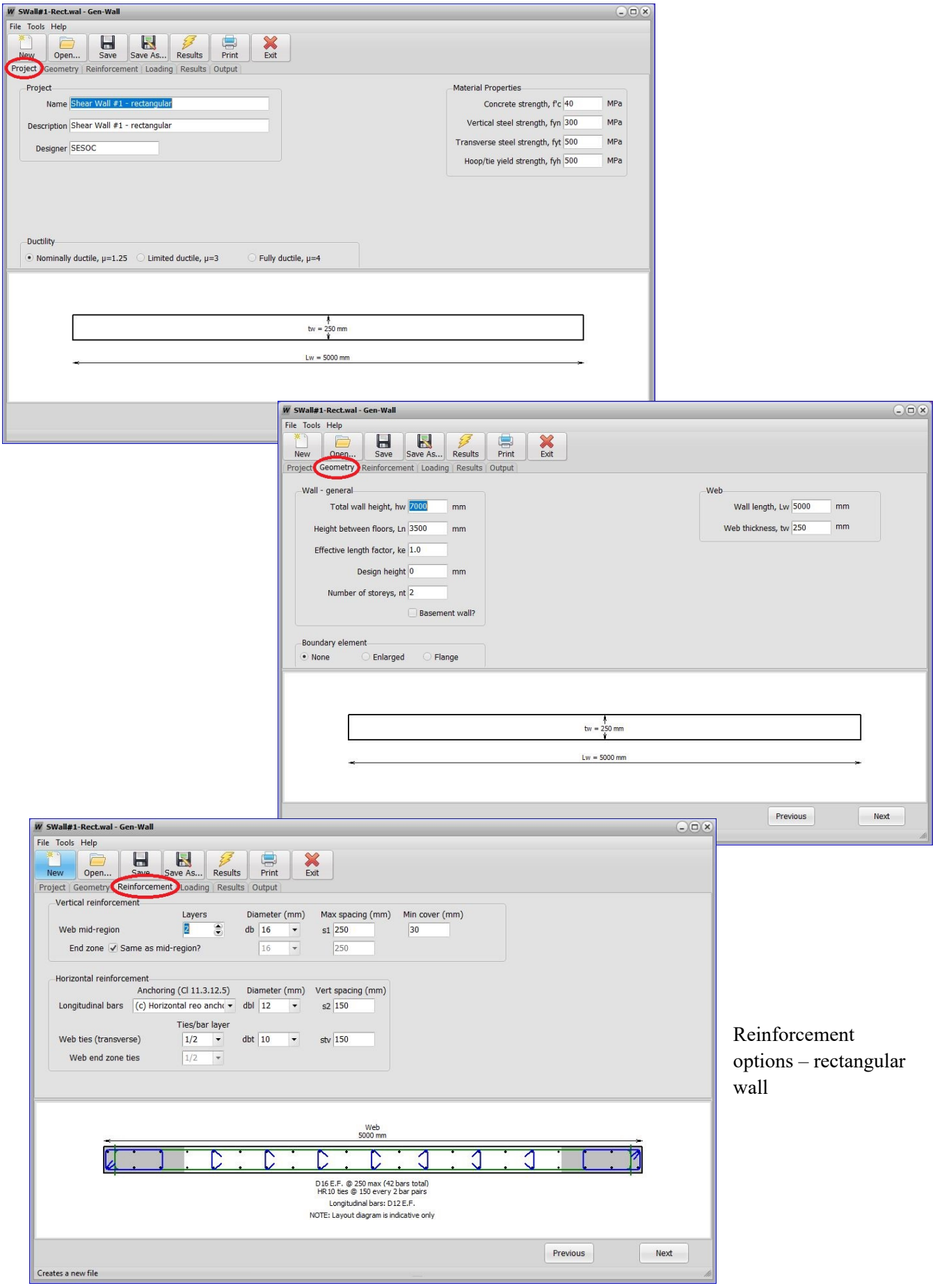
Depending on the chosen wall type, unnecessary input fields are hidden, in order to focus the user's attention on the necessary data content.

Data input tabs are as follows:

- Project
- Geometry
- Reinforcement
- Loading
- Results
- Output

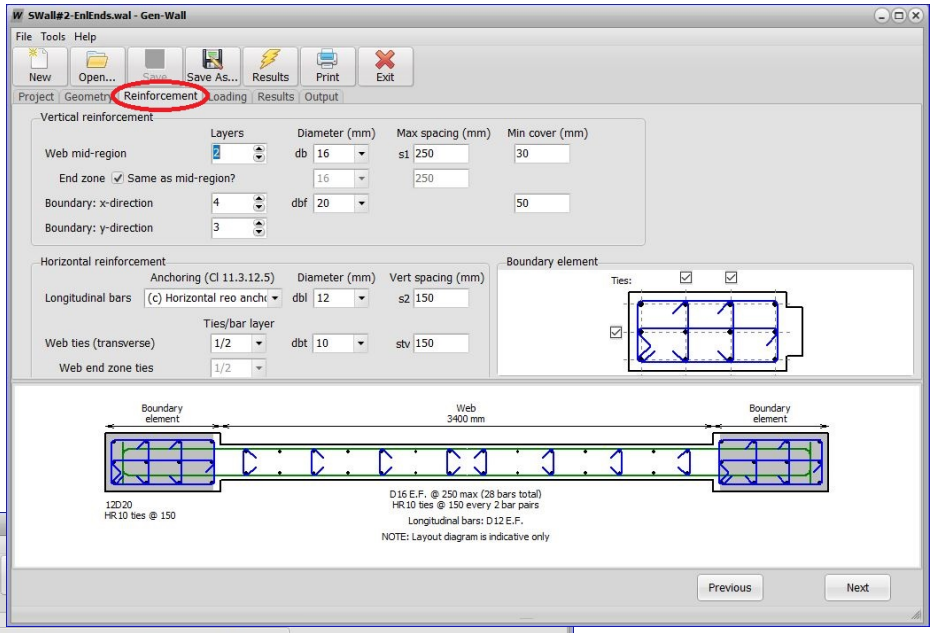


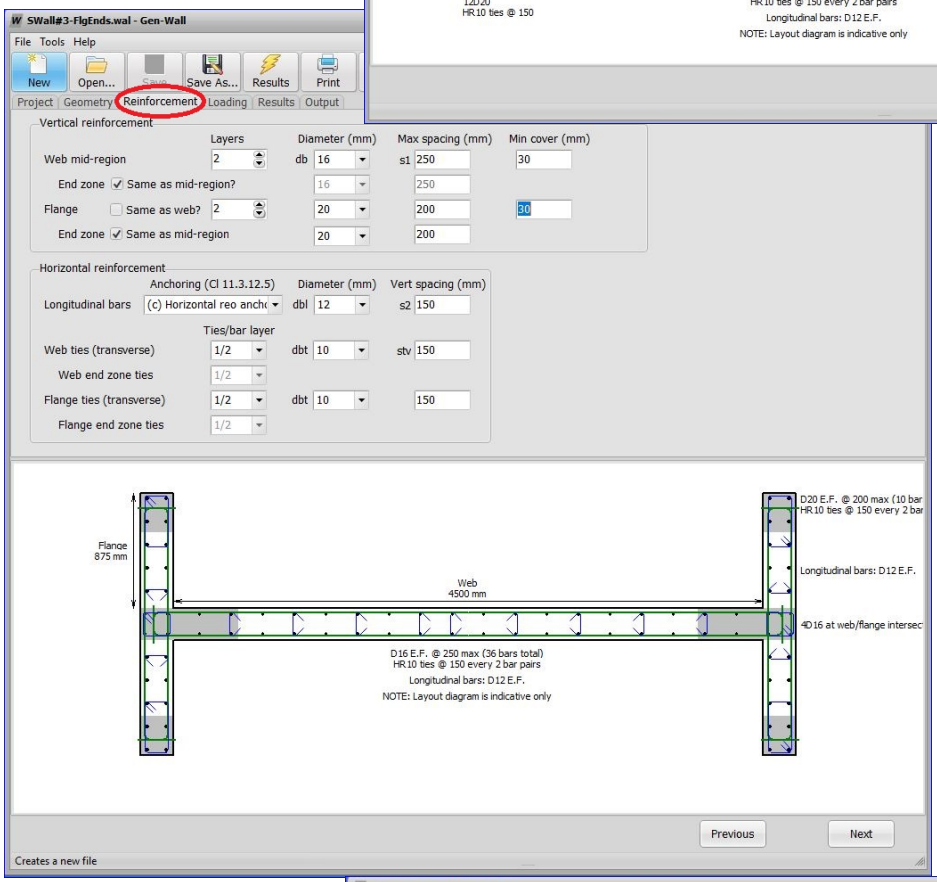
The following series of screenshots demonstrate the look and feel of the interface, program structure, and input parameters required:



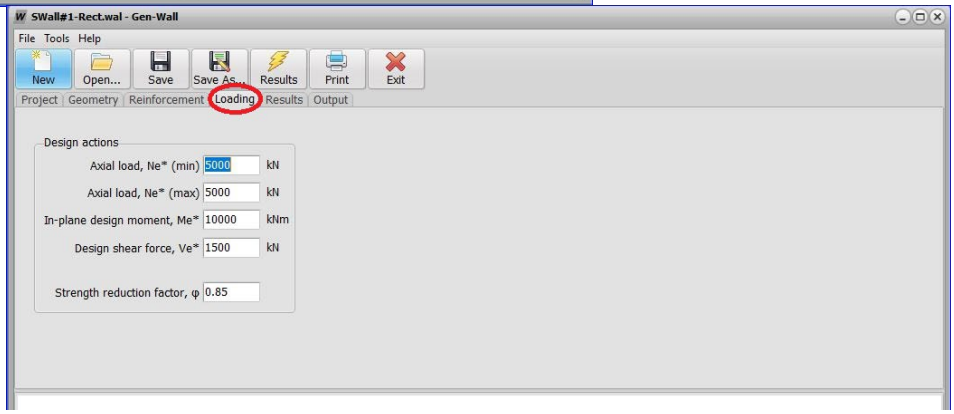
Reinforcement options – rectangular wall

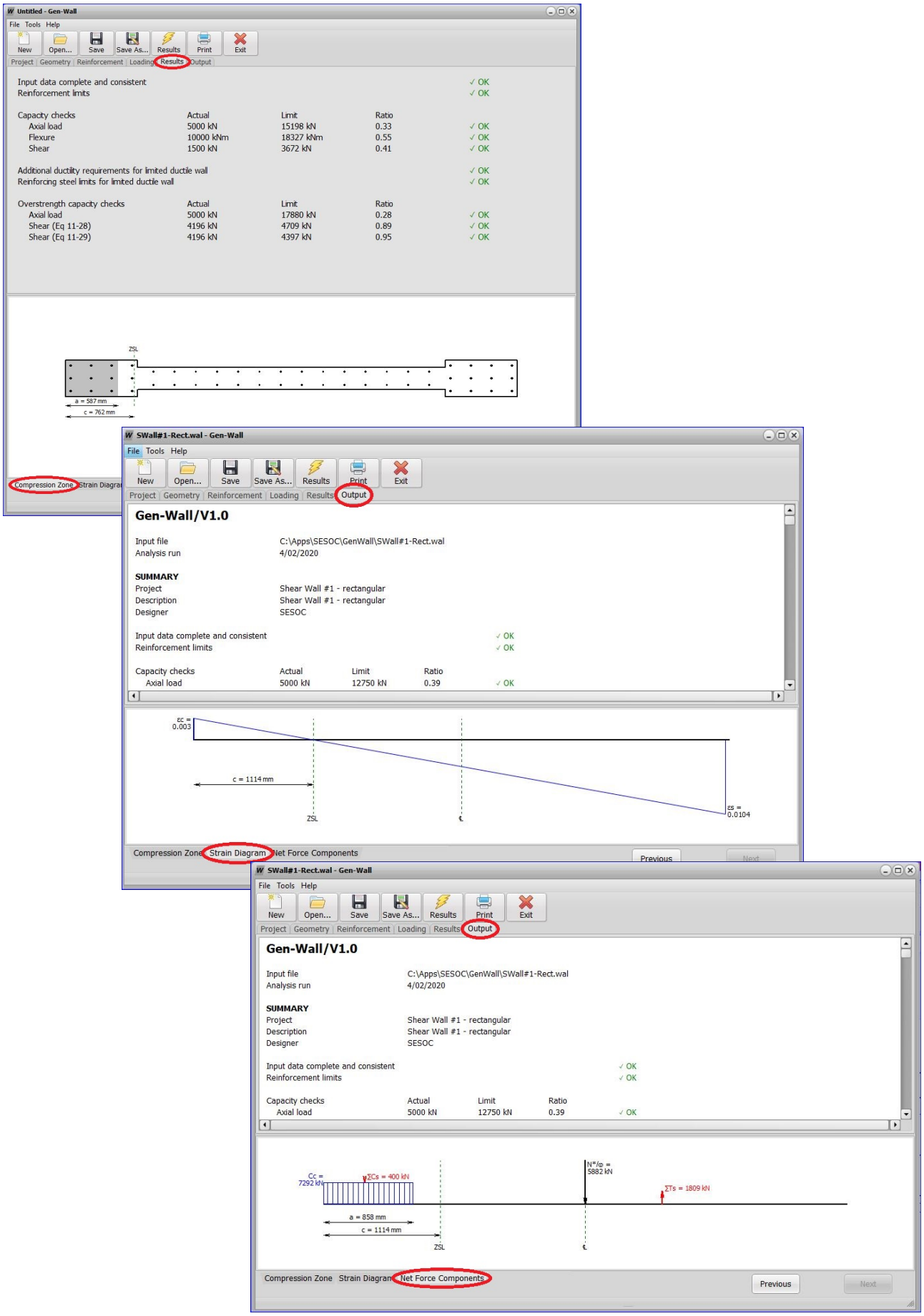
… and with enlarged ends





…and with flanged ends




Untitled - Gen-Wall
File Tools Help
New Open... Save Save As... Results Print Exit
Project Geometry Reinforcement Loading Results Output
Input data complete and consistent ✓ OK
Reinforcement limits ✓ OK
Capacity checks Actual Limit Ratio
Axial load 5000 kN 15198 kN 0.33 ✓ OK
Flexure 10000 kNm 18327 kNm 0.55 ✓ OK
Shear 1500 kN 3672 kN 0.41 ✓ OK
Additional ductility requirements for limited ductile wall ✓ OK
Reinforcing steel limits for limited ductile wall ✓ OK
Overstrength capacity checks Actual Limit Ratio
Axial load 5000 kN 17880 kN 0.28 ✓ OK
Shear (Eq 11-28) 4196 kN 4709 kN 0.89 ✓ OK
Shear (Eq 11-29) 4196 kN 4397 kN 0.95 ✓ OK
ZSL
a = 587 mm
c = 762 mm
Compression Zone Strain Diagram
SWall#1-Rect.wal - Gen-Wall
File Tools Help
New Open... Save Save As... Results Print Exit
Project Geometry Reinforcement Loading Results Output
Gen-Wall/V1.0
Input file C:\Apps\SESOC\GenWall\SWall#1-Rect.wal
Analysis run 4/02/2020
SUMMARY
Project Shear Wall #1 - rectangular
Description Shear Wall #1 - rectangular
Designer SESOC
Input data complete and consistent ✓ OK
Reinforcement limits ✓ OK
Capacity checks Actual Limit Ratio
Axial load 5000 kN 12750 kN 0.39 ✓ OK
εc = 0.003
c = 1114 mm
ZSL
εs = 0.0104
Compression Zone Strain Diagram Net Force Components
Previous Next
SWall#1-Rect.wal - Gen-Wall
File Tools Help
New Open... Save Save As... Results Print Exit
Project Geometry Reinforcement Loading Results Output
Gen-Wall/V1.0
Input file C:\Apps\SESOC\GenWall\SWall#1-Rect.wal
Analysis run 4/02/2020
SUMMARY
Project Shear Wall #1 - rectangular
Description Shear Wall #1 - rectangular
Designer SESOC
Input data complete and consistent ✓ OK
Reinforcement limits ✓ OK
Capacity checks Actual Limit Ratio
Axial load 5000 kN 12750 kN 0.39 ✓ OK
Cc = 7292 kN
ΣCs = 400 kN
N*/φ = 5882 kN
ΣTs = 1809 kN
a = 858 mm
c = 1114 mm
ZSL
Compression Zone Strain Diagram Net Force Components
Previous Next

3.4 Aspects of Particular Note

3.4.1 Conceptual Layout versus Detailing

Gen-Wall attempts to show, as accurately as possible, the wall geometry and conceptual layout of reinforcing, for the purpose of accurate implementation of code checks.

It is not, however, a detailing program – the finer details of bar laps, end anchorage and termination etc. are of necessity left to the designer. Thus, there may be, at times, unusual aspects in terms of the graphical presentation, e.g. 90° bend terminations protruding from the wall.

The designer is expected to attend to the minutiae of exact bar placement, bend radii, etc.

3.4.2 Vertical Reinforcement Layout

Gen-Wall automatically lays out vertical reo along a web or flange and within an enlarged boundary element based on a minimal number of parameters specified by the user. This gives a fast and convenient way to quickly input and update layout during design, but does not give full control of exact bar locations to the user for a non-standard layout, e.g. irregular bar spacings.

Separate input is provided for end-zone and mid-regions. To minimise input requirements, Gen-Wall has the option to set end-zone reinforcement data to be the same as those for the mid-region, and/or set flange reinforcement data to be the same as those for web.

3.4.3 Hoops/Ties/Stirrups

Again, Gen-Wall automatically generates ties based on user-specified parameters. Arrangement of ties along the web or flange is primarily determined by the specified ties per pair of vertical bars (1/1 to 1/4).

3.4.4 Horizontals – Layout and Termination

The user has a choice of three different horizontal bar end terminations:

- Horizontal bar laps
- Corner bars anchored with hooks and local ties
- Horizontal reo anchored at all end with 90° hooks and surrounding cage

These are presented irrespective of the wall type, through some are more suitable for different wall type(s) than others.

3.4.5 Confinement to Ends

As confinement to the wall ends is required in virtually all situations, and horizontals bar diameter plus deformations plus higher yield steel results in a (typically) larger radius bend, closed hoops are automatically provided to the wall end.

Geometry and sizing are ascertained according to the relevant ‘Web ties’ information.

3.4.6 Plane Strain Assumption

The program is a sectional analysis tool, based upon the ‘plane strain’ assumption, as per NZS 3101. It is the responsibility of the designer to ensure compliance with this assumption, especially around transition areas, where this assumption may not be valid, and to design/detail accordingly, e.g. shear wall founded on end poles.

3.4.7 Overstrength Calculations

While ‘elastic’ analysis – and the ‘plane strain’ assumption form the core of the program, such an approach does not hold true for overstrength calculation, in which the wall may have undergone any number of cycles previously, and thus the ‘commencing’ strain, and hence yield stress, is unknown. Thus, in accordance with industry practice – and code expectations, steel is assumed to be at full yield, in compression or tension, on each side of the ‘zero strain line’ (ZSL).

However, from a computational perspective, this has been ‘softened’ to a small region of ‘linearity’ around the ZSL, in order to provide a more ‘transitional’ apportionment of steel tension and compression components versus the abrupt changes otherwise – especially with e.g. a flanged wall end.

3.4.8 Output Results

As indicated on the screenshots above, two levels of results are provided:

- Summary results
- Detailed output

Summary results present the key design stages as a series of single-line descriptions with a stage results (OK, FAIL, or CHECK). Capacity values and limits are provided for axial load, flexure, and shear.

Detailed output is displayed on-screen (and printout) with detailed equations and cross-references to the relevant NZS 3101 clause and equation numbers. This allows the designer to manually verify Gen-Wall’s approach and specific implementation of NZS 3101.

4 OVERVIEW – CURRENT SOFTWARE

4.1 Current Software Listing

Software currently available to SESOC members is listed below, and capabilities briefly outlined in the subsequent sections:

- Soils
- BeamDes
- Gen-Col
- MemDes & MemDes+

4.2 Soils

The soils program provides three main areas of capability, with sub-categories under each of these, as follows:

- Shallow Foundations:
  - Pad Footings (Rectangular and Circular)
  - Strip Footing (Restrained and Unrestrained)
- Deep Foundations:
  - Piles (Free and Head Restrained)
- Retaining:
  - Cantilever Pole Retaining Walls
  - Reinforced Concrete Retaining Walls

The program is currently based on B1/VM4, though of necessity, implementing a number of aspects beyond that document. However, due to a number of factors – including the absence of an agreed industry retaining wall design basis, SESOC has embarked on development of a documented process for both CTP and RC retaining walls. These are addressed further, later.

4.3 Gen-Col

Gen-Col is a reinforced concrete column design program, based on NZS 3101 (1997), with capabilities as follows:

- Sections:
  - Circular
  - Square and Rectangular
  - I-, T-, and L-Shaped
- Design Functionality
  - Axial Plus Uni-Directional Flexure
  - Axial Plus Bi-Axial Flexure
  - Full Interaction Curve Analysis
  - Defined Moment Analysis

This program was originally developed at the University of Auckland by Khalid Al-Sayegh, under the supervision of Dr Richard Fenwick.

4.4 MemDes – Steel Segment Design

MemDes is a comprehensive steel member/segment design program, originally developed by the author, of New Zealand Steel at that time, and launched 1998.

MemDes includes design capabilities encompassing:

- Sections:
  - The full range of standard UB, UC, RSC, CHS, SHS & RHS sections
  - Custom welded I sections, including tapered members
  - Spiral welded pipe – library & custom
- Design:
  - Flexure, axial, shear and combined actions
  - Temperature: ambient plus fire design
  - Elastic through to fully ductile design
  - User specified restraint conditions

MemDes is based on NZS 3404:1997 design provisions.

4.5 MemDes Plus – Beam Analysis and Design Functionality

On the back of the successful MemDes program, it was decided to extend this to provide member design capabilities.

In summary, the aim was to provide integrated ***analysis – strength – serviceability*** design functionality all in a single program. It is simple, intuitive, and efficient to use, and intended to benefit designers across a wide range of practices and structure types.

In some more detail, the capabilities include:

- Analysis of a single steel member, prismatic and library only
- End supports: simple, fixed, or user defined end moments
- Loading: trapezoidal (including UDL) and point loads
- Basic load combinations with user defined load factors
- Member segmentation: multiple, regularly spaced, with user input of restraint conditions
- Member strength check: flexure and shear only
- Member serviceability check

- Output calculations: input summary, plus detailed calculations (if required)

4.6 Basic BeamDes

This program provides simple reinforced concrete beam design. Originally developed as a simpler and easier to use program on the back of its 'parent' BeamDes, nevertheless, it still provides significant design options and capabilities, as below.

The section types include: Tee, L, rectangular, and slab, with a range of support conditions including external, internal, cantilever and simply-supported. The user is able to specify yield position information, rebar layer locations, rebar size and numbers, etc, with the program undertaking significant checks to ensure code compliance. Results include both moment and shear capacities, as well as beam overstrength.

The interface is, arguably, now rather dated. We would be happy to update, should sufficient feedback be received.

5 CONCLUSION

This paper has provided an insight into the pending Gen-Wall RC shear wall design software, due to be released around the time of this conference. It has also provided an outline of the software currently available, free, to SESOC members.

REFERENCES

[1] SESOC Software Overview, 2017, Geoff Bird, SESOC Conference 2017 proceedings