Contents

permanent_wall_design.m

Structural design script for supplemental exterior wall (PERMANENT CONDITION ONLY) Design per CSA A23.3 (concrete design code)

DESIGN APPROACH: Wall acts as simply supported between top wall segment and floor slab Designed for permanent earth pressure and surcharge loads Reinforcement sized per CSA A23.3 requirements

NOTE: This analysis does NOT include temporary stability during construction (See additional_wall_design.m for complete analysis including temporary works)

```
clear; clc; close all;
```

INPUTS

Soil parameters

```
soil.phi_deg        = 32;          % internal friction angle (degrees)
soil.gamma          = 19;          % unit weight (kN/m^3)
soil.surcharge      = 12;          % uniform surcharge at grade (kPa)
soil.K0_method      = 'Jaky';      % method for at-rest coefficient

% Geometry (all dimensions in metres)
geo.total_height    = 5.6;         % total wall height from slab to grade (m)
geo.top_segment     = 2.6;         % thickness of top wall segment (m)
geo.top_offset      = 1.0;         % depth below grade where new wall begins (m)
geo.wall_width      = 1.0;         % design strip width (m)
geo.wall_thickness  = 0.5;        % assumed thickness of new wall element (m)
geo.cover_tension   = 0.075;       % clear cover to reinforcement (m)

% Material properties
concrete.fc         = 30;          % concrete compressive strength (MPa)
concrete.phi_flex   = 0.9;         % resistance factor for flexure
concrete.phi_shear  = 0.65;        % resistance factor for shear
steel_rebar.fy      = 400;         % yield strength of reinforcement (MPa)

% Load factors per CSA (user may adjust as required)
factors.gamma_earth = 1.5;         % factor for earth and surcharge loads
```

DERIVED PARAMETERS

```
switch soil.K0_method
    case 'Jaky'
        soil.K0 = 1 - sind(soil.phi_deg);
    otherwise
        error('Unsupported K0 calculation method.');
end

fprintf('==========================================================================\n');
fprintf('PERMANENT WALL DESIGN - SIMPLY SUPPORTED MODEL\n');
fprintf('CSA A23.3 (Concrete Design)\n');
fprintf('==========================================================================\n\n');
fprintf('At-rest earth pressure coefficient K0 = %.3f\n\n', soil.K0);

% Effective height of new wall
geo.effective_height = geo.total_height - geo.top_offset;
if geo.effective_height <= 0
    error('Effective height must be positive. Check top_offset relative to total height.');
end

% Depth vectors
n_pts = 200;
y = linspace(0, geo.effective_height, n_pts).';  % local coordinate from top of new wall (m)
z_global = y + geo.top_offset;                   % depth below grade (m)
```

```
========================================================================
PERMANENT WALL DESIGN - SIMPLY SUPPORTED MODEL
CSA A23.3 (Concrete Design)
========================================================================

At-rest earth pressure coefficient K0 = 0.470
```

LATERAL PRESSURE DISTRIBUTION

```
pressure_soil = soil.K0 .* soil.gamma .* z_global;         % kPa (kN/m^2)
pressure_surcharge = soil.K0 .* soil.surcharge .* ones(size(z_global)); % kPa
pressure_total = pressure_soil + pressure_surcharge;       % kPa

% Convert to line load for 1 m strip (kN/m)
load_line = pressure_total .* geo.wall_width;
load_line = load_line(:);  % ensure column vector
load_line_factored = load_line * factors.gamma_earth;

fprintf('LATERAL PRESSURE DISTRIBUTION:\n');
fprintf('  Surcharge pressure: %.2f kPa\n', soil.K0 * soil.surcharge);
fprintf('  Max soil pressure (at base): %.2f kPa\n', soil.K0 * soil.gamma * geo.effective_height);
fprintf('  Total max pressure: %.2f kPa\n\n', max(pressure_total));
```

```
LATERAL PRESSURE DISTRIBUTION:
  Surcharge pressure: 5.64 kPa
  Max soil pressure (at base): 41.09 kPa
  Total max pressure: 55.66 kPa
```

SIMPLY SUPPORTED BEAM MODEL

Wall is supported at top (by existing wall) and at bottom (by floor slab) Lateral earth pressure acts as distributed load

```
L = geo.effective_height;  % span length (m)

% Total resultant load (unfactored and factored)
W_total = trapz(y, load_line);                % kN
W_total_factored = trapz(y, load_line_factored); % kN

% Calculate reactions for simply supported beam with trapezoidal load
% Using integration to find centroid of load
y_centroid = trapz(y, y .* load_line) / W_total;  % location of resultant from top

% Reactions (taking moments about supports)
R_top = W_total * (L - y_centroid) / L;        % Reaction at top support (kN)
R_bottom = W_total * y_centroid / L;           % Reaction at bottom support (kN)
R_top_factored = W_total_factored * (L - y_centroid) / L;
R_bottom_factored = W_total_factored * y_centroid / L;

% Calculate shear and moment at multiple points along span
V = zeros(size(y));
M = zeros(size(y));
V_u = zeros(size(y));
M_u = zeros(size(y));

for i = 1:numel(y)
    % Shear: V(z) = R_top - integral of load from 0 to z
    if i > 1
        load_above = trapz(y(1:i), load_line(1:i));
        load_above_factored = trapz(y(1:i), load_line_factored(1:i));
    else
        load_above = 0;
        load_above_factored = 0;
    end
    V(i) = R_top - load_above;
    V_u(i) = R_top_factored - load_above_factored;

    % Moment: M(z) = R_top * z - moment of loads above
    if i > 1
        moment_loads = 0;
        moment_loads_factored = 0;
        for j = 1:(i-1)
            lever_arm = y(i) - y(j);
            moment_loads = moment_loads + load_line(j) * lever_arm * (y(2)-y(1));
            moment_loads_factored = moment_loads_factored + load_line_factored(j) * lever_arm * (y(2)-y(1));
        end
        M(i) = R_top * y(i) - moment_loads;
        M_u(i) = R_top_factored * y(i) - moment_loads_factored;
    else
        M(i) = 0;
        M_u(i) = 0;
```

```
    end
end

% Find maximum values
[moment_max, idx_max] = max(M);
[moment_max_factored, idx_max_factored] = max(M_u);
shear_max = max(abs(V));
shear_max_factored = max(abs(V_u));
location_max_moment = y(idx_max_factored);

fprintf('STRUCTURAL ANALYSIS (Simply Supported Model):\n');
fprintf('  Span length: %.2f m\n', L);
fprintf('  Total lateral load: %.1f kN/m (factored: %.1f kN/m)\n', W_total, W_total_factored);
fprintf('  Top reaction: %.1f kN/m (factored: %.1f kN/m)\n', R_top, R_top_factored);
fprintf('  Bottom reaction: %.1f kN/m (factored: %.1f kN/m)\n', R_bottom, R_bottom_factored);
fprintf('  Max moment: %.1f kN·m/m at z=%.2f m (factored: %.1f kN·m/m)\n', ...
    moment_max, location_max_moment, moment_max_factored);
fprintf('  Max shear: %.1f kN/m (factored: %.1f kN/m)\n\n', shear_max, shear_max_factored);

% For design, use maximum values
moment_base_factored = moment_max_factored;
shear_base_factored = shear_max_factored;
```

```
STRUCTURAL ANALYSIS (Simply Supported Model):
  Span length: 4.60 m
  Total lateral load: 161.5 kN/m (factored: 242.3 kN/m)
  Top reaction: 65.0 kN/m (factored: 97.5 kN/m)
  Bottom reaction: 96.5 kN/m (factored: 144.8 kN/m)
  Max moment: 93.3 kN·m/m at z=2.52 m (factored: 140.0 kN·m/m)
  Max shear: 96.5 kN/m (factored: 144.8 kN/m)
```

FLEXURAL DESIGN (CSA A23.3)

Geometry in mm

```
b = geo.wall_width * 1000;                          % mm
t_mm = geo.wall_thickness * 1000;                   % mm
cover_mm = geo.cover_tension * 1000;                % mm

% Rebar catalogue (metric)
rebar_db = [11.3, 15.9, 19.5, 25.2, 29.9, 35.7];  % bar diameters (mm) for 10M-35M
rebar_area = [100, 200, 300, 500, 700, 1000];      % areas (mm^2)
rebar_label = {'10M','15M','20M','25M','30M','35M'};

% Assume tension reinforcement on OTHER SIDE (away from soil, towards existing wall)
% This is the tension face for simply supported beam under lateral pressure
effective_d = t_mm - cover_mm - rebar_db/2;       % mm (array per bar size)

Mu_Nmm = moment_base_factored * 1e6;              % convert kN·m to N·mm
fc = concrete.fc;                                  % MPa (N/mm^2)
fy = steel_rebar.fy;                               % MPa
phi_f = concrete.phi_flex;

% Solve for required steel area using iterative approach
% Start with estimate
d_use = t_mm - cover_mm - 20;  % assume 30-35M bars, d ≈ t - cover - 20mm
alpha1 = max(0.67, 0.85 - 0.0015 * fc);
beta1 = max(0.67, 0.97 - 0.0025 * fc);

% Iterative solution for As
As_trial = Mu_Nmm / (phi_f * fy * 0.9 * d_use);  % Initial estimate (assume jd = 0.9d)
for iter = 1:10
    c = As_trial * fy / (alpha1 * fc * b);
    a = beta1 * c;
    jd = d_use - a/2;
    Mr_trial = phi_f * As_trial * fy * jd;
    if abs(Mr_trial - Mu_Nmm) / Mu_Nmm < 0.01
        break;
    end
    As_trial = Mu_Nmm / (phi_f * fy * jd);
end
As_required = As_trial;

% Minimum and maximum reinforcement ratios (CSA A23.3 Clause 11)
rho_min = 0.0025;
rho_max = 0.025;
As_min = rho_min * b * geo.wall_thickness * 1000;
As_max = rho_max * b * geo.wall_thickness * 1000;

As_required = max(As_required, As_min);
if As_required > As_max
    warning('Required steel exceeds maximum code ratio. Increase wall thickness.');
end
```

```
% Select practical reinforcement (nearest spacing not exceeding 300 mm)
max_spacing = 300;      % mm
min_spacing = 100;      % mm
n_layers = 1;           % number of reinforcement layers

provided = struct('label','-', 'spacing', NaN, 'As', 0, 'd', NaN, 'layers', 1);
for idx = numel(rebar_area):-1:1  % try larger bars first for economy
    Ab = rebar_area(idx);
    d_eff = effective_d(idx);
    spacing = Ab * 1000 / As_required; % mm
    if spacing <= max_spacing && spacing >= min_spacing
        As_provided = Ab * (1000 / spacing);
        provided.label = rebar_label{idx};
        provided.spacing = spacing;
        provided.As = As_provided;
        provided.d = d_eff;
        provided.layers = 1;
        break;
    end
end

% If single layer doesn't work, try double layer with same bar size
if isnan(provided.spacing)
    for idx = numel(rebar_area):-1:1
        Ab = rebar_area(idx);
        d_eff = effective_d(idx);
        spacing = Ab * 2000 / As_required; % double layer, so 2x area per spacing
        if spacing <= max_spacing && spacing >= min_spacing
            As_provided = Ab * (2000 / spacing);  % 2 layers
            provided.label = rebar_label{idx};
            provided.spacing = spacing;
            provided.As = As_provided;
            provided.d = d_eff;
            provided.layers = 2;
            break;
        end
    end
end

if isnan(provided.spacing)
    warning('Unable to satisfy reinforcement demand even with double layer. Increase wall thickness.');
end

% Strength check with provided reinforcement
As_prov_total = provided.As;
a_depth = As_prov_total * fy / (0.85 * fc * b);
Mn_provided = As_prov_total * fy * (provided.d - a_depth / 2);  % N·mm
phiMn = phi_f * Mn_provided;

fprintf('FLEXURAL DESIGN (CSA A23.3):\n');
fprintf('  Wall thickness: %.0f mm\n', t_mm);
fprintf('  Required As: %.0f mm²/m\n', As_required);
if provided.layers == 1
    fprintf('  Provided: %s @ %.0f mm (single layer)\n', provided.label, provided.spacing);
else
    fprintf('  Provided: 2 layers of %s @ %.0f mm\n', provided.label, provided.spacing);
end
fprintf('  Area provided: %.0f mm²/m\n', As_prov_total);
fprintf('  Factored moment capacity: %.1f kN·m/m\n', phiMn/1e6);
fprintf('  Factored moment demand: %.1f kN·m/m\n', moment_base_factored);

if phiMn < Mu_Nmm
    fprintf('  STATUS: INADEQUATE - Increase wall thickness or reinforcement\n\n');
else
    fprintf('  STATUS: OK (Capacity/Demand = %.2f)\n\n', phiMn/Mu_Nmm);
end
```

```
FLEXURAL DESIGN (CSA A23.3):
  Wall thickness: 500 mm
  Required As: 1250 mm²/m
  Provided: 20M @ 240 mm (single layer)
  Area provided: 1250 mm²/m
  Factored moment capacity: 182.5 kN·m/m
  Factored moment demand: 140.0 kN·m/m
  STATUS: OK (Capacity/Demand = 1.30)
```

SHEAR CHECK

```
lambda_c = 1.0;     % density factor for normal-weight concrete
Vc = 0.2 * lambda_c * sqrt(fc) * b * provided.d;    % N
phiVc = concrete.phi_shear * Vc;
Vu_N = shear_base_factored * 1e3;  % convert kN to N
```

```
fprintf('SHEAR CHECK (CSA A23.3):\n');
fprintf('  Factored shear capacity: %.1f kN/m\n', phiVc/1e3);
fprintf('  Factored shear demand: %.1f kN/m\n', shear_base_factored);

if phiVc < Vu_N
    fprintf('  STATUS: INADEQUATE - Consider shear reinforcement or thicker wall\n\n');
else
    fprintf('  STATUS: OK (Capacity/Demand = %.2f)\n\n', phiVc/Vu_N);
end
```

```
SHEAR CHECK (CSA A23.3):
  Factored shear capacity: 295.7 kN/m
  Factored shear demand: 144.8 kN/m
  STATUS: OK (Capacity/Demand = 2.04)
```

OUTPUT SUMMARY TABLE

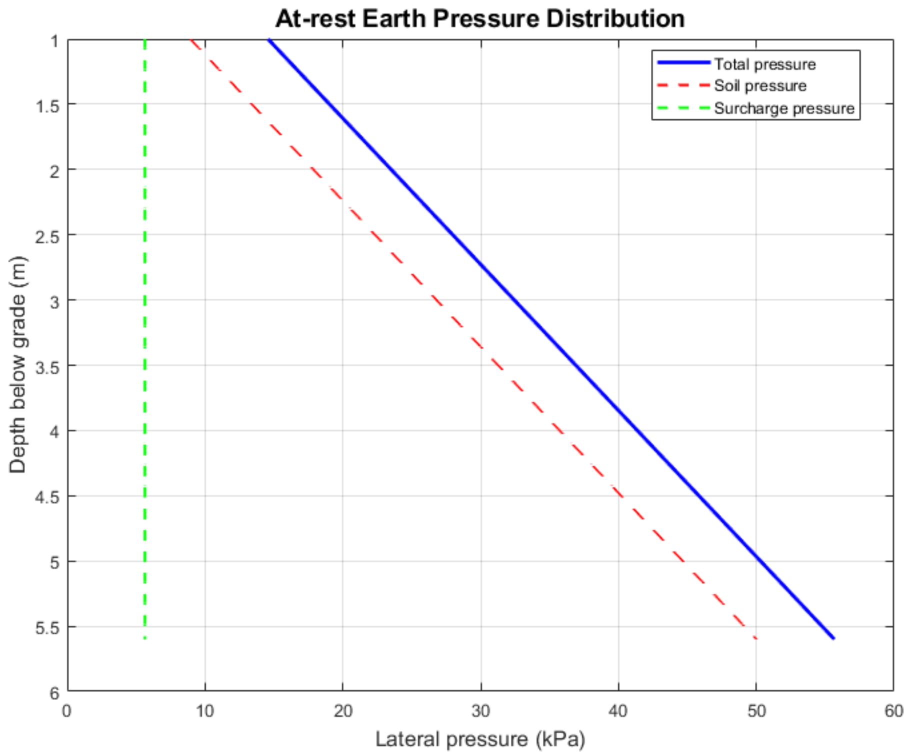
```
summary = table;
summary.Description = {'Wall thickness (mm)'; ...
                       'Tension reinforcement'; ...
                       'Rebar spacing (mm)'; ...
                       'Factored max moment (kN·m/m)'; ...
                       'Factored max shear (kN/m)'; ...
                       'Moment capacity (kN·m/m)'; ...
                       'Shear capacity (kN/m)'; ...
                       'Top reaction (kN/m)'; ...
                       'Bottom reaction (kN/m)'};

% Format reinforcement description
if provided.layers == 1
    rebar_desc = sprintf('%s @ %.0f mm', provided.label, provided.spacing);
else
    rebar_desc = sprintf('2 layers %s @ %.0f mm', provided.label, provided.spacing);
end

summary.Value = [t_mm; ...
                 string(rebar_desc); ...
                 provided.spacing; ...
                 moment_base_factored; ...
                 shear_base_factored; ...
                 phiMn/1e6; ...
                 phiVc/1e3; ...
                 R_top_factored; ...
                 R_bottom_factored];

fprintf('===========================================================================\n');
fprintf('DESIGN SUMMARY TABLE:\n');
fprintf('===========================================================================\n');
disp(summary);
```

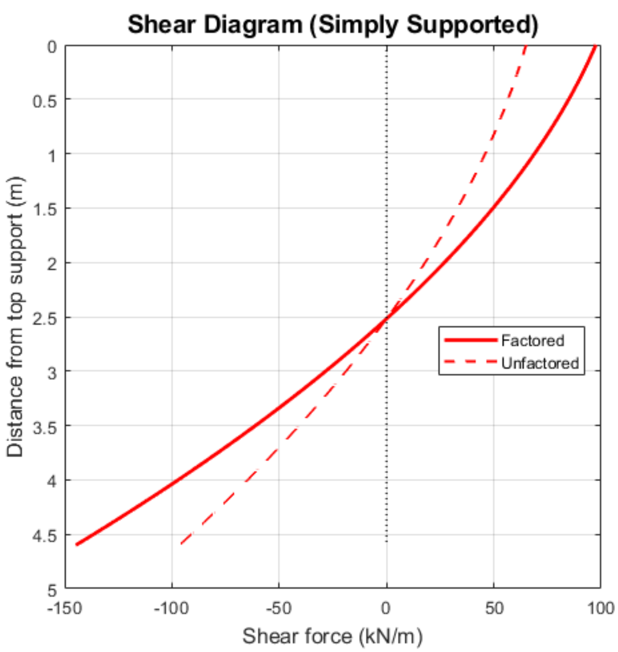
```
===========================================================================
DESIGN SUMMARY TABLE:
===========================================================================
              Description                  Value
    ________________________________    ______________

    {'Wall thickness (mm)'          }    "500"
    {'Tension reinforcement'        }    "20M @ 240 mm"
    {'Rebar spacing (mm)'           }    "240"
    {'Factored max moment (kN·m/m)'}    "139.9826"
    {'Factored max shear (kN/m)'    }    "144.772"
    {'Moment capacity (kN·m/m)'     }    "182.4507"
    {'Shear capacity (kN/m)'        }    "295.6743"
    {'Top reaction (kN/m)'          }    "97.5218"
    {'Bottom reaction (kN/m)'       }    "144.772"
```

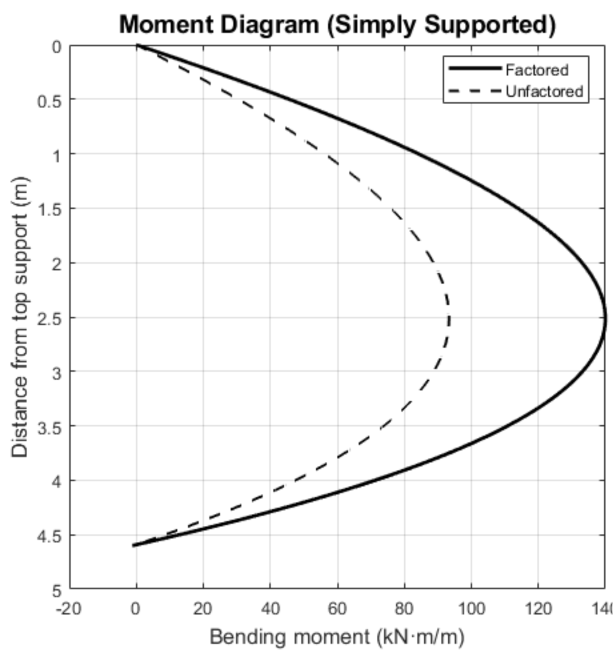
PLOTS

```
figure('Name','Earth Pressure Diagram','Position',[100 100 800 600]);
plot(pressure_total, z_global, 'b-', 'LineWidth', 2);
hold on;
plot(pressure_soil, z_global, 'r--', 'LineWidth', 1.5);
plot(pressure_surcharge, z_global, 'g--', 'LineWidth', 1.5);
grid on;
set(gca,'YDir','reverse');
xlabel('Lateral pressure (kPa)', 'FontSize', 12);
ylabel('Depth below grade (m)', 'FontSize', 12);
title('At-rest Earth Pressure Distribution', 'FontSize', 14, 'FontWeight', 'bold');
legend('Total pressure', 'Soil pressure', 'Surcharge pressure', 'Location', 'best');
```

```
figure('Name','Shear and Moment Diagrams','Position',[150 150 1200 500]);
subplot(1,2,1);
plot(V_u, y, 'r-', 'LineWidth', 2); grid on;
hold on;
plot(V, y, 'r--', 'LineWidth', 1.5);
plot([0 0], [0 L], 'k:', 'LineWidth', 1);  % Zero line
set(gca,'YDir','reverse');
xlabel('Shear force (kN/m)', 'FontSize', 12);
ylabel('Distance from top support (m)', 'FontSize', 12);
title('Shear Diagram (Simply Supported)', 'FontSize', 14, 'FontWeight', 'bold');
legend('Factored', 'Unfactored', 'Location', 'best');

subplot(1,2,2);
plot(M_u, y, 'k-', 'LineWidth', 2); grid on;
hold on;
plot(M, y, 'k--', 'LineWidth', 1.5);
set(gca,'YDir','reverse');
xlabel('Bending moment (kN·m/m)', 'FontSize', 12);
ylabel('Distance from top support (m)', 'FontSize', 12);
title('Moment Diagram (Simply Supported)', 'FontSize', 14, 'FontWeight', 'bold');
legend('Factored', 'Unfactored', 'Location', 'best');
```







DESIGN NOTES

```
fprintf('\n============================================================================\n');
fprintf('DESIGN NOTES:\n');
fprintf('===========================================================================\n');
disp('1. STRUCTURAL MODEL: Simply supported wall between top and floor slab');
disp('2. Wall designed for permanent earth pressure and surcharge per CSA A23.3');
disp('3. Load factors: γ = 1.5 for earth pressure and surcharge');
disp('4. Resistance factors: ϕc = 0.65 (shear), ϕf = 0.9 (flexure)');
disp('5. Concrete: M30 (fc'' = 30 MPa), normal weight (λ = 1.0)');
disp('6. Reinforcement: Grade 400 (fy = 400 MPa)');
disp('7. Tension reinforcement on face away from soil (towards existing wall)');
disp('8. Design assumptions: At-rest earth pressure (Kₒ method)');
disp('9. Bottom connection to slab: Assumed as pinned support');
disp('10. Top connection: Assumed as pinned support (no moment transfer)');
disp('11. IMPORTANT: This analysis covers PERMANENT condition only');
disp('12. Temporary construction stability NOT included in this analysis');
```

```
disp('13. For complete design including temporary works, see additional_wall_design.m');
fprintf('============================================================================\n');
```

```
============================================================================
DESIGN NOTES:
============================================================================
1. STRUCTURAL MODEL: Simply supported wall between top and floor slab
2. Wall designed for permanent earth pressure and surcharge per CSA A23.3
3. Load factors: γ = 1.5 for earth pressure and surcharge
4. Resistance factors: ϕc = 0.65 (shear), ϕf = 0.9 (flexure)
5. Concrete: M30 (fc' = 30 MPa), normal weight (λ = 1.0)
6. Reinforcement: Grade 400 (fy = 400 MPa)
7. Tension reinforcement on face away from soil (towards existing wall)
8. Design assumptions: At-rest earth pressure (Kₒ method)
9. Bottom connection to slab: Assumed as pinned support
10. Top connection: Assumed as pinned support (no moment transfer)
11. IMPORTANT: This analysis covers PERMANENT condition only
12. Temporary construction stability NOT included in this analysis
13. For complete design including temporary works, see additional_wall_design.m
============================================================================
```