Case 2 - Pressurised & unrestraned pipe - [2] § 8.1.2

Hoop stress $\sigma_h := \sigma_{h'}$ $\sigma_h = 21.53\ MPa$

Circumferential stress (max) $\sigma_c := \sigma_{q'} + \sigma_{h'}$ $\sigma_c = 34.25\ MPa$

Circumferential stress (min) $\sigma_{c'} := -\sigma_{q'} + \sigma_{h'}$ $\sigma_{c'} = 8.8\ MPa$

Longitudinal axial stresses (max) $\sigma_{a2} := \sigma_{at'} + \sigma_{ax}$ $\sigma_{a2} = 70.43\ MPa$

Longitudinal axial stresses (min) $\sigma_{a2'} := -\sigma_{at'} + \sigma_{ax}$ $\sigma_{a2'} = -52.42\ MPa$

Von Mises equivalent stress

Membrane stresses components

$\sigma_{e1} := \sqrt{\sigma_h^2 + \sigma_{a2}^2 - \sigma_h \cdot \sigma_{a2}}$ $\sigma_{e1} = 62.51\ MPa$

$\sigma_{e2} := \sqrt{\sigma_h^2 + \sigma_{a2'}^2 - \sigma_h \cdot \sigma_{a2'}}$ $\sigma_{e2} = 65.87\ MPa$

$\sigma_e := \max\left(\sigma_{e1}, \sigma_{e2}\right)$ $\sigma_e = 65.87\ MPa$

Membrane stress utilisation $UTL_{m2} := \dfrac{\sigma_e}{\sigma'_{mem}}$ $UTL_{m2} = 0.28$

Membrane & bending stresses

$\sigma_{e3} := \sqrt{\sigma_c^2 + \sigma_{a2}^2 - \left(\sigma_c \cdot \sigma_{a2}\right)}$ $\sigma_{e3} = 61\ MPa$

$\sigma_{e4} := \sqrt{\sigma_c^2 + \sigma_{a2'}^2 - \left(\sigma_c \cdot \sigma_{a2'}\right)}$ $\sigma_{e4} = 75.6\ MPa$

$\sigma_{e5} := \sqrt{\sigma_{c'}^2 + \sigma_{a2}^2 - \left(\sigma_{c'} \cdot \sigma_{a2}\right)}$ $\sigma_{e5} = 66.47\ MPa$

$\sigma_{e6} := \sqrt{\sigma_{c'}^2 + \sigma_{a2'}^2 - \left(\sigma_{c'} \cdot \sigma_{a2'}\right)}$ $\sigma_{e6} = 57.33\ MPa$

$\sigma_{eq} := \max\left(\sigma_{e3}, \sigma_{e4}, \sigma_{e5}, \sigma_{e6}\right)$ $\sigma_{eq} = 75.6\ MPa$

Membrane & bending stress utilisation $UTL_{s2} := \dfrac{\sigma_{eq}}{\sigma'_{stress}}$ $UTL_{s2} = 0.29$

Case 3 - Pressurised & restraned [2] § 8.1.2

Hoop stress	$\sigma_h := \sigma_{h'}$	$\sigma_h = 21.53\ MPa$
Circumferential stress (max)	$\sigma_c := \sigma_{q'} + \sigma_{h'}$	$\sigma_c = 34.25\ MPa$
Circumferential stress (min)	$\sigma_{c'} := -\sigma_{q'} + \sigma_{h'}$	$\sigma_{c'} = 8.8\ MPa$
Longitudinal axial stresses (max)	$\sigma_{a3} := \sigma_{at'} + \sigma_{ax'}$	$\sigma_{a3} = 67.88\ MPa$
Longitudinal axial stresses (min)	$\sigma_{a3'} := -\sigma_{at'} + \sigma_{ax'}$	$\sigma_{a3'} = -54.97\ MPa$

Von Mises equivalent stress

Membrane stresses components

$$\sigma_{e1'} := \sqrt{\sigma_h^{\ 2} + \sigma_{a3}^{\ 2} - \sigma_h \cdot \sigma_{a3}} \qquad \sigma_{e1'} = 60.08\ MPa$$

$$\sigma_{e2'} := \sqrt{\sigma_h^{\ 2} + \sigma_{a3'}^{\ 2} - \sigma_h \cdot \sigma_{a3'}} \qquad \sigma_{e2'} = 68.32\ MPa$$

$$\sigma_{e'} := \max\left(\sigma_{e1'}, \sigma_{e2'}\right) \qquad \sigma_{e'} = 68.32\ MPa$$

Membrane stress utilisation

$$UTL_{m3} := \frac{\sigma_{e'}}{\sigma'_{mem}} \qquad UTL_{m3} = 0.29$$

Membrane & bending stresses

$$\sigma_{e3'} := \sqrt{\sigma_c^{\ 2} + \sigma_{a3}^{\ 2} - \left(\sigma_c \cdot \sigma_{a3}\right)} \qquad \sigma_{e3'} = 58.79\ MPa$$

$$\sigma_{e4'} := \sqrt{\sigma_c^{\ 2} + \sigma_{a3'}^{\ 2} - \left(\sigma_c \cdot \sigma_{a3'}\right)} \qquad \sigma_{e4'} = 77.95\ MPa$$

$$\sigma_{e5'} := \sqrt{\sigma_{c'}^{\ 2} + \sigma_{a3}^{\ 2} - \left(\sigma_{c'} \cdot \sigma_{a3}\right)} \qquad \sigma_{e5'} = 63.94\ MPa$$

$$\sigma_{e6'} := \sqrt{\sigma_{c'}^{\ 2} + \sigma_{a3'}^{\ 2} - \left(\sigma_{c'} \cdot \sigma_{a3'}\right)} \qquad \sigma_{e6'} = 59.86\ MPa$$

$$\sigma_{eq'} := \max\left(\sigma_{e3'}, \sigma_{e4'}, \sigma_{e5'}, \sigma_{e6'}\right) \qquad \sigma_{eq'} = 77.95\ MPa$$

Membrane & bending stress utilisation

$$UTL_{s3} := \frac{\sigma_{eq'}}{\sigma'_{stress}} \qquad UTL_{s3} = 0.3$$

§7.6.1 Operating, depressurised & occasional load cases summary

Membrane stress utilisation

$$UTL_{mem} := \max\left(UTL_{m1}, UTL_{m2}, UTL_{m3}\right) \qquad UTL_{mem} = 29.4\%$$

Membrane & bending stress utilisation

$$UTL_{bs} := \max\left(UTL_{s1}, UTL_{s2}, UTL_{s3}\right) \qquad UTL_{bs} = 29.9\%$$

As it can be seen the Von Mises equivalent stresses are below the allowable yield utilisation as defined in T/SP/GM/1 [Ref. 2], hence the stresses can be considered acceptable.

§7.7 Cyclic Loading Assessment - [2] §8.1.3

In accordance with T/SP/CE/12 (Ref [2] §8.1.3) the maximum principle stress range due to traffic loadings is calculated based on FLM3 Load Model as presented in BS EN 1991-2 (Ref [1] §4.6.4).

Pipe cover $H_{min} = 1.5\ m$

Load Model FLM3 [1] §4.6.4

Adjustment factor $\alpha_{FLM3} := 1$

Axle load (with DAF applied) $Q_{FLM3} := 120\ kN \cdot \alpha_{FLM3}$ $Q_{FLM3} = 120\ kN$

Wheel load $q_{FLM3} := \dfrac{Q_{FLM3}}{2}$ $q_{FLM3} = 60\ kN$

Maximum wheel loading, allowing for load case concidered in section 4 $q_{res} := \max\left(q_{FLM3}, q_{res'}\right)$ $q_{res} = 114.2\ kN$

Allowable stress range due to cyclic traffic loading [2] §8.1.3 $\Delta\sigma_{allow} := 35\ MPa$

Where the daily maximum hoop stress is less than 35MPa a full fatigue assessment is not required. Hoop stress from FLM3 [Ref 1] is calculated below:

§7.7.1 Daily maximum principle stress range

Maximum resultant normal stress on the pipe assuming it is loaded directly above the pipe - Boussinesq Equation [5] Pg 336 $q_{FLM3'} := \dfrac{3 \cdot q_{res} \cdot H_{min}^{\ 3}}{2 \cdot \pi \cdot H_{max}^{\ 5}}$ $q_{FLM3'} = 17.55\ kPa$

Vertical surcharge loading from traffic loadings [3] §C.5.1 $Q_{FLM3'} := q_{FLM3'} \cdot OD_{tot}$ $Q_{FLM3'} = 2.03\ kN \cdot m^{-1}$

Total vertical surcharge (soil, yard & traffic) $Q_{tot'} := Q_k + Q_{rc} + Q_{FLM3'}$ $Q_{tot'} = 5.26\ kN \cdot m^{-1}$

Hoop stress from vertical loads (using FLM3) $\sigma_{v'} := \dfrac{Q_{tot'}}{2 \cdot th_{min}}$ $\sigma_{v'} = 0.5\ MPa$

Utilisation - stress range from traffic loading $UTS_{\Delta\sigma} := \dfrac{\sigma_{v'}}{\Delta\sigma_{allow}}$ $UTS_{\Delta\sigma} = 0.01$

As the daily maximum hoop stress is less than 35MPa a full fatigue assessment is not required. An assessment looking at vertical variable pressure increase over the pipe is calculated below:

§7.7.2 Cyclic loadings - vertical variable pressure increase

The cyclic loading from traffic can be considered acceptable when the pressure increase is below:

Allowable pressure increase from traffic loading - [2] §8.1.3	$\sigma_{allow} := \dfrac{64\ \mathbf{MPa}}{\left(\dfrac{OD_{pipe}}{th_{pipe}}\right)^2}$	$\sigma_{allow} = 182\ \mathbf{kPa}$

Fatigue Load model 3 - FLM3 [1] §4.6.4

Wheel load	$q_{FLM3} := 120\ \mathbf{kN}$	$q_{FLM3} = 120\ \mathbf{kN}$
Contact width	$B_{FLM3} := 400\ \mathbf{mm}$	
Contact length	$L_{FLM3} := 400\ \mathbf{mm}$	
Vertical transient pressure - LM3	$\Delta\sigma := \dfrac{q_{FLM3}}{\left(B_{FLM3} + H_{eq}\right) \cdot \left(L_{FLM3} + H_{eq}\right)}$	$\Delta\sigma = 19.77\ \mathbf{kPa}$
Utilisation - stress range from traffic loading	$UTS_{\Delta\sigma'} := \dfrac{\Delta\sigma}{\sigma_{allow}}$	$UTS_{\Delta\sigma'} = 0.11$

The cyclic loading from traffic is below the limit set for FLM3, hence the stresses can be considered acceptable.

§8 Summary

§8.1 Pipe Utilisation

$$UTL := \max\left(UTL_{hoop}, UTL_{q}, UTL_{q'}, UTL_{mem}, UTL_{bs}, UTS_{\Delta\sigma}, UTS_{\Delta\sigma'}, UTL_{defl}, UTL_{pe}\right)$$

$$UTL = 40.53\%$$

$$Check_{UTL} := \begin{array}{l} \text{if } 1 - UTL > 0 \\ \quad \text{return "PASS"} \\ \text{return "FAIL"} \end{array}$$

$$Check_{UTL} = \text{"PASS"}$$

§8.2 Conclusion of Pipe Analysis

The pipeline has been checked for the following in accordance with the acceptance criteria as listed in T/SP/GM/1.

1. Internal Pressure [6] - §8.1.1 — $\sigma_{hoop} \le$ SMYS * 0.72
2. Operating, Depressurised & Occasional Load Cases [6] - §8.1.2
   a. Membrane and Bending — $\sigma_e \le$ 0.9 x SMYS
   b. Membrane — $\sigma_e \le$ 0.8 x SMYS
3. Cyclic Loading - §8.1.3 — $\Delta\sigma < \dfrac{64\ MPa}{\left(\dfrac{OD_{pipe}}{th_{pipe}}\right)^2}$
4. Over-deflection (Ovality) - §8.2 — $\delta_y \le$ 5% x Pipe diameter
5. Buckling Stability - §8.3 — Elastic FOS > 3.0

The assessment has confirmed that all the above acceptance criteria are satisfied based on the assessment methodology and assumptions defined in §1.5, and the input data defined in §2, hence the crossing proposed is deemed fit for purpose.

Appendix B – Design Residual Risk Register

DESIGNER'S RESIDUAL RISK REGISTER

Project Name:	WHITE HOUSE FARM, HOUSING DEVELOPMENT	**Design Required:**	SURFACE LOAD CALCULATION OVER AN EXISTING GAS MAIN
Client:	TIDSWELL CHILD	**Design No.**	CDC-038
Designer:	A GRADY	**Date:**	30/01/2020

Ref	Hazard	Control Measures	Owner
1	Inaccurate information provided for calculation	Client to review the information provided and used within the calculation to confirm that information is correct.	Construction Team
2	Damage to the asset and other services during construction of the road	No excavation will be required around the main.	Construction Team
3	Ground conditions and depths vary from design.	Trial pits have been dug in the vicinity of the main which correspond with historic borehole records in the area, both are contain within Appendix E.	Construction Team
4	Vehicle loadings exceed designed loading.	Load assessments to be carried out in compliance with design guidance and standards. Loadings have been assessed as per BS EN 1991-2 (2003).	Construction Team
5	Exposure to contaminated soils.	Appropriate contamination investigation to have been undertaken previous to works. Correct PPE requirements met for ground types	Construction Team
6	Surrounding environment	Separation of work area from pedestrians and vehicles. Water courses to be protected from spills/ contamination (if applicable).	Construction Team

7	Slips, trips and falls	Good housekeeping to be maintained on site. Maintain good access and egress at working area at all times. All work to be carried out in daylight hours or to be risk assessed for lighting.	Construction Team

Appendix C – Site Drawings and Construction Detail

No Dimensions are to be scaled from this drawing.

Contractors must verify all figured dimensions at site before commencing any work or making any Shop drawings.

No.	Revisions	By	Date

N
W E
S

0 10m

DRAINAGE NOTES

Connection to the existing mains foul drainage is proposed subject to the final site constraints and approval of the relevant authorities including Cadent Gas. If mains connection is not possible, a new sewage treatment plant will be installed as indicated.

- INDICATIVE MAINS DRAINAGE ROUTE
- INDICATIVE SEWAGE TREATMENT PLANT

- INDICATIVE PROPOSED TREES
- EXISTING TREES
- INDICATIVE NEW HEDGE PLANTING
- INDICATIVE BURIED GAS PIPELINE AND 6M EASEMENT
- OVERHEAD POWER LINES
- Existing crushed stone field access
- New crushed stone driveway and parking
- Shared Access
- Bin/Refuse Storage/Collection

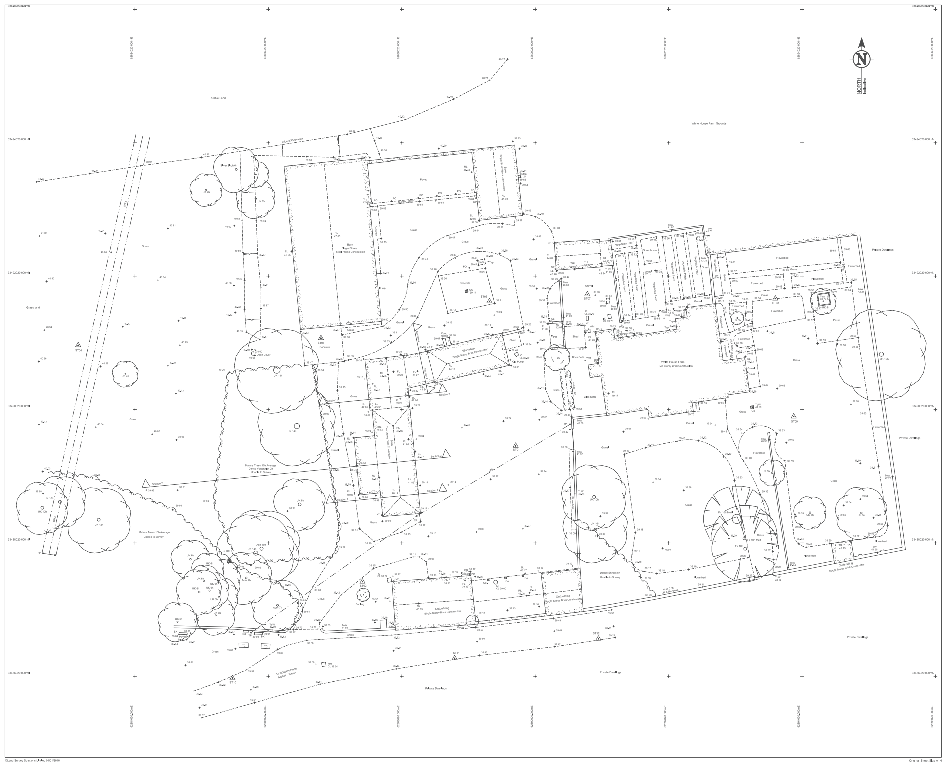
Tidswell Childs
CHARTERED BUILDING SURVEYORS . ARCHITECTURAL CONSULTANCY

Tidswell Childs LLP
The Meeting Room, Old Chapel Way
Broadland Business Park, Norwich. NR7 0WG
Tel : 01603 443344

Client	Project
Mr & Mrs P Birkbeck	PROPOSED NEW DWELLING White House, Mundesley Road, Trunch

Drawing Title	Drawn	Scale
PROPOSED SITE BLOCK PLAN	ric	1:200 @ A1
	Date: JAN 20	Sheet: A1

Project Number	Drawing Number	Revision	Revision Date
19.041	002	G	09.06.20



TOPOGRAPHICAL & MEASURED BUILDING SURVEYS

ABBREVIATIONS & SYMBOLS

AH	Arch Head Height	FH	Fire Hydrant	RSJ	Rolled Steel Joist
AR	Assumed Route	FBD	Floor Board Direction	SI	Sign Post
AV	Air Valve	FH	Fire Hydrant	SP	Arch Spring Point Height
BB	Belisha Beacon	FL	Floor Level	SV	Stop Valve
BH	Bore Hole	FP	Flag Pole	SW	Surface Water
BL	Bed Level	FW	Foul Water	SY	Stay
BO	Bollard	GG	Gully Grate	Tac	Tactile Paving
BrP	Brace Post	GV	Gas Valve	TC	Telecom Cover
BS	Bus Stop	HH	Head Height	TH	Trial Pit
BU	Bush	IC	Inspection Cover	THL	Threshold Level
B/W	Barbed Wire Fence	IL	Invert Level	TL	Traffic Light
BX	Box (Utilities)	I/R	Iron Railings	ToW	Top of Wall
C/B	Close Board Fence	KO	Kerb Outlet	TP	Telegraph Pole
CH	Cill Height	LP	Lamp Post	TV	Cable TV Cover
CL	Cover Level	MH	Manhole	UB	Universal Beam
C/L	Chain Link Fence	MP	Marker Post	UC	Unknown Cover
C-Lev	Ceiling Level	NB	Name Board	UK	Unknown Tree
Col	Column	OHL	Overhead Line (approx)	USB	Under Side Beam
C/P	Chestnut Paling Fence	Pan	Panel Fence	UTL	Unable To Lift
CR	Cable Riser	PB	Post Box	VP	Vent Pipe
DC	Drainage Channel	PM	Parking Meter	WB	Waste Bin
DH	Door Head Height	PO	Post	WH	Weep Hole
DP	Down Pipe	P/R	Post & Rail Fence	WL	Water Level
DR	Drain	P/W	Post & Wire Fence	WM	Water Meter
EL	Eaves Level	P/Wall	Partition Wall	WO	Wash Out
EP	Electric Pole	RE	Rodding Eye	(symbol)	Floor to Ceiling Height
ER	Earth Rod	RL	Ridge Level		
ET	EP+Transformer	RP	Reflector Post	(symbol) F/C	Floor to False Ceiling Ht
FB	Flower Bed	RS	Road Sign		
FBD	Floor Board Direction	RSD	Roller Shutter Door	(symbol)	Survey Control Station

DRAWING NOTE

Topographical Surveys

Trees are drawn to scale showing the average canopy spread. Descriptions and heights should be used as a guide only.

All building names, descriptions, number of storeys, construction type including roof line details are indicative only and taken externally from ground level.

All below ground details including drainage, voids and services have been identified from above ground and therefore all details relating to these features including; sizes, depth, description etc will be approximate only. All critical dimensions and connections should be checked and verified prior to starting work.

Detail, services and features may not have been surveyed if obstructed or not reasonably visible at the time of the survey.

Measured Building Surveys

Measurements to internal walls are taken to the wall finishes at approx 1m above the floor level and the wall assumed to be vertical.

Cill heights are measured as floor to the cill and head heights are measured from cill to the top of window.

General

The contractor must check and verify all site and building dimensions, levels, utilities and drainage details and connections prior to commencing work. Any errors or discrepancies must be notified to Survey Solutions immediately.

The accuracy of the digital data is the same as the plotting scale implies. All dimensions are in metres unless otherwise stated.

The survey control listed is only to be used for topographical surveys at the stated scale. All control must be checked and verified prior to use.

Do not scale from this drawing.

SURVEY CONTROL CO-ORDINATES

STATIONS	EASTINGS	NORTHINGS	LEVEL	DESCRIPTION
ST01	628897.072	334894.567	39.237	Peg & Nail
ST02	628874.109	334874.192	39.399	Peg & Nail
ST03	628854.201	334877.293	39.963	Peg & Nail
ST04	628831.494	334909.637	40.433	Peg & Nail
ST05	628867.882	334910.899	39.701	PK Nail
ST06	628893.143	334916.223	39.154	PK Nail
ST07	628907.816	334917.259	39.731	Peg & Nail
ST08	628935.998	334916.624	39.588	Hilti Nail
ST09	628938.751	334898.948	39.596	Peg & Nail
ST10	628854.621	334859.720	39.529	PK Nail
ST11	628887.929	334862.706	39.422	PK Nail
ST12	628909.483	334865.639	39.289	PK Nail

SURVEY GRID AND LEVEL DATUM

Ordnance Survey (OS) national grid coordinates have been established for survey control point ST01 using GPS and related to OSTN02(GB) and OSGM02(GB). The survey grid is orientated to Grid North with a scale factor of 1.000.

All levels relate to the Ordnance Survey (OS) level datum at survey control point ST01 established by GPS using OSGM02(GB).

REV	DESCRIPTION	DRAWN	APPR	DATE

SURVEY SOLUTIONS

Ipswich Coventry Yeovil Norwich Perth Nottingham Brentwood

Tel No: 0845 0405 969 Fax No: 0845 0405 970
www.survey-solutions.co.uk enquiries@survey-solutions.co.uk

LAND SURVEYING BUILDING SURVEYING UNDERGROUND SURVEYING

PROJECT TITLE
WHITE HOUSE FARM, MUNDESLEY ROAD, TRUNCH, NORTH WALSHAM, NORFOLK, NR28 0QB.

DRAWING DETAIL
TOPOGRAPHICAL SURVEY
Sheet 1 of 1

CLIENT				SCALE
TIDSWELL CHILDS LLP				1:200
SURVEYOR	SURVEY DATE	CHECKED BY	APPROVED BY	DWG STATUS
MG	26/05/2015	DMG	JIA	FINAL
DRAWING NUMBER			REVISION	ISSUE DATE
15844ea-01				09/06/2015

Original Sheet Size A1H