Numerical techniques for design calculations of longitudinal bending in buried steel pipes subjected to lateral Earth movements

Mohamed Almahakeri, Ian D. Moore and Amir Fam

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Review timeline
Original submission: 7 November 2018
1st revised submission: 12 April 2019
2nd revised submission: 28 May 2019
Final acceptance: 31 May 2019

Note: Reports are unedited and appear as submitted by the referee. The review history appears in chronological order.

Review History
RSOS-181550.R0 (Original submission)

Review form: Reviewer 1

Is the manuscript scientifically sound in its present form?
No

Are the interpretations and conclusions justified by the results?
No

Is the language acceptable?
No

Is it clear how to access all supporting data?
No
Do you have any ethical concerns with this paper?
No

Have you any concerns about statistical analyses in this paper?
I do not feel qualified to assess the statistics

Recommendation?
Major revision is needed (please make suggestions in comments)

Comments to the Author(s)
This paper provides numerical results from the analysis of pipes pulled horizontally through sand. The flow in the manuscript is weak in places and important information required in a paper focusing on modeling is missing. There is a disproportionate emphasis at the beginning on the experimental programme that had been carried out previously and published elsewhere. Given the large end displacements, up to 30 mm, progressive failure would be expected, which cannot be properly accommodated by the constitutive model. Some specifics include:

1. The English must be improved. In some places it is awkward, there are spelling mistakes and inappropriate words or grammatical tense are used. Take for example, the third sentence in the introduction. Soil instability may be considered a soil failure but soil creep is a mechanism. Also referring to 5 lines down from the top of page 2 the word focused should probably be replaced by focusing. On page 2, line 30: analyses is spelt incorrectly.

2. Figure 9 appears to be referred to before Figure 8.

3. It is clear from the introduction that the paper focuses on analysis, yet section 2 provides a disproportionate amount of information on the “Testing Program”. From a numerical analysis point of view, it would have been sufficient to show the basic layout of the test being analyzed (not the facility) and the properties of the soil, including a figure of a typical stress-strain response of the sand. Had the sand been dense, it would probably have undergone post-peak softening that would have included shear banding. For such a case a constant dilation angle would have been inappropriate and local progressive failure would have taken place before the peak load would have been reached that reflects a macro-scale measure. The reviewer is aware that only the behavior up to peak was of interest.

4. The reviewer appreciates that a commercial code was used and that low-order elements are favoured for problems involving contact and large displacements. Were the stress and strain rate measures objective? Also, the 3-D 8-node element is known to have problems if bending modes are present, say adjacent to the pipe. Was selective (not reduced) integration used to improve the performance of the 8-node element?

5. Page 6, line 58: What does the quadrilateral element response have to do with the triangular element response? In section 4.2 it was made clear that the 2-D, 6-node triangular element was used. There are ways of predicting softer responses with 3-node triangular elements.

6. Page 7, Line 39: Should likely be referring to Figure 12 not 11.

7. Section 5.5: Just because ASCE charts go up to a friction angle of 45, is not a good reason to use the residual strength for carrying out the analysis.

Review form: Reviewer 2

Is the manuscript scientifically sound in its present form?
Yes

Are the interpretations and conclusions justified by the results?
Yes
This paper presents experimental data and numerical simulations of tests investigating the behavior of buried steel pipelines subjected to lateral earth movement. The presented experimental data are useful for understanding pipeline behavior and for future numerical model calibration by other researchers. The presented numerical modeling, including the Janbu expression for the elastic modulus distribution with depth, is based on rather simple, standard procedures. The conclusions derived from the comparisons of the experimental measurements and the numerical results seem to be reasonable. Therefore, this reviewer recommends publication of the article.

Review form: Reviewer 3

Is the manuscript scientifically sound in its present form?
No

Are the interpretations and conclusions justified by the results?
Yes

Is the language acceptable?
No

Is it clear how to access all supporting data?
Yes

Do you have any ethical concerns with this paper?
No

Have you any concerns about statistical analyses in this paper?
Yes

Recommendation?
Major revision is needed (please make suggestions in comments)
Comments to the Author(s)

The paper needs substantial improvement in terms of writing, analysis and presentation before publishing. Some points to consider are as below. Subroutine incorporated modelling shows improvement in prediction of pipe response. But, the paper needs improvement by highlighting the its main contribution and significance.

• Please highlight the significance of research work (such as need of incorporating stress dependent E value)
• Line 46 p.1; it would be appropriate to use third person language in the manuscript
• Line 35 p.2: Please add more description of the tests; such as soil condition, soil type, etc
• Line 18 page4; cohesion of 1kpa can be excessive for dry sand. Please verify the selection
• Line 21 page4; please provide reference for dilation angle use
• Fig.5; large mesh sensitivity can be observed. Please define the mesh size in fine, medium and coarse mesh. Also, provide number of elements in each approach
• Section 4.5; please compare the model prediction of load-displacement curve with the experiments
• Please also compare peak load/(soil unit weight x height x diameter x length) as the guidelines are based on this scale
• Results and discussion section has not been written well. It needs improvement in terms of presentation and rigorous analysis.
• Would pipe pulling load same as pipe lateral load?
• It is clear from literature that plane strain and structured elements are the most suitable element type for this problem (lateral pipeline analysis). I am not sure why authors want to present this parametric study on element types? It appears not significant to present in the paper
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• Even with Janbu’s incorporation, there is substantial difference in peak load and mobilization in Fig. 17. Please discuss
• It would be useful to propose analytical model for bending moment based on the numerical predictions using janbu’s stress dependent formulation

Decision letter (RSOS-181550.R0)

07-Mar-2019

Dear Dr Almahakeri,

The editors assigned to your paper ("NUMERICAL TECHNIQUES FOR DESIGN CALCULATIONS OF LONGITUDINAL BENDING IN BURIED STEEL PIPES SUBJECTED TO LATERAL EARTH MOVEMENTS") have now received comments from reviewers. We would like you to revise your paper in accordance with the referee and Associate Editor suggestions which can be found below (not including confidential reports to the Editor). Please note this decision does not guarantee eventual acceptance.

Please submit a copy of your revised paper before 30-Mar-2019. Please note that the revision deadline will expire at 00.00am on this date. If we do not hear from you within this time then it will be assumed that the paper has been withdrawn. In exceptional circumstances, extensions may be possible if agreed with the Editorial Office in advance. We do not allow multiple rounds of revision so we urge you to make every effort to fully address all of the comments at this stage. If deemed necessary by the Editors, your manuscript will be sent back to one or more of the
original reviewers for assessment. If the original reviewers are not available, we may invite new reviewers.

To revise your manuscript, log into http://mc.manuscriptcentral.com/rsos and enter your Author Centre, where you will find your manuscript title listed under "Manuscripts with Decisions." Under "Actions," click on "Create a Revision." Your manuscript number has been appended to denote a revision. Revise your manuscript and upload a new version through your Author Centre.

When submitting your revised manuscript, you must respond to the comments made by the referees and upload a file "Response to Referees" in "Section 6 - File Upload". Please use this to document how you have responded to the comments, and the adjustments you have made. In order to expedite the processing of the revised manuscript, please be as specific as possible in your response.

In addition to addressing all of the reviewers' and editor's comments please also ensure that your revised manuscript contains the following sections as appropriate before the reference list:

• Ethics statement (if applicable)
If your study uses humans or animals please include details of the ethical approval received, including the name of the committee that granted approval. For human studies please also detail whether informed consent was obtained. For field studies on animals please include details of all permissions, licences and/or approvals granted to carry out the fieldwork.

• Data accessibility
It is a condition of publication that all supporting data are made available either as supplementary information or preferably in a suitable permanent repository. The data accessibility section should state where the article's supporting data can be accessed. This section should also include details, where possible of where to access other relevant research materials such as statistical tools, protocols, software etc can be accessed. If the data have been deposited in an external repository this section should list the database, accession number and link to the DOI for all data from the article that have been made publicly available. Data sets that have been deposited in an external repository and have a DOI should also be appropriately cited in the manuscript and included in the reference list.

If you wish to submit your supporting data or code to Dryad (http://datadryad.org/), or modify your current submission to dryad, please use the following link:
http://datadryad.org/submit?JournalID=RSOS&manu=RSOS-181550

• Competing interests
Please declare any financial or non-financial competing interests, or state that you have no competing interests.

• Authors’ contributions
All submissions, other than those with a single author, must include an Authors’ Contributions section which individually lists the specific contribution of each author. The list of Authors should meet all of the following criteria; 1) substantial contributions to conception and design, or acquisition of data, or analysis and interpretation of data; 2) drafting the article or revising it critically for important intellectual content; and 3) final approval of the version to be published.

All contributors who do not meet all of these criteria should be included in the acknowledgements.
We suggest the following format:
AB carried out the molecular lab work, participated in data analysis, carried out sequence alignments, participated in the design of the study and drafted the manuscript; CD carried out the statistical analyses; EF collected field data; GH conceived of the study, designed the study, coordinated the study and helped draft the manuscript. All authors gave final approval for publication.

• Acknowledgements
Please acknowledge anyone who contributed to the study but did not meet the authorship criteria.

• Funding statement
Please list the source of funding for each author.

Once again, thank you for submitting your manuscript to Royal Society Open Science and I look forward to receiving your revision. If you have any questions at all, please do not hesitate to get in touch.

Kind regards,
Andrew Dunn
Royal Society Open Science Editorial Office
Royal Society Open Science
openscience@royalsociety.org

on behalf of Prof R. Kerry Rowe (Subject Editor)
openscience@royalsociety.org

Associate Editor’s comments:
Please accept our apologies for the delay in completing review of your manuscript: we struggled to recruit suitable referees as rapidly as we (and, no doubt, you) had hoped. Nevertheless, we have now secured the commentary of three reviewers. As you will see, there are a number of matters that need to be addressed before the manuscript may be considered further. Please incorporate the changes requested by the reviewers and, if you do not do so, provide full rebuttals for any absences -- if you are unable to satisfy the reviewers that the paper is ready for acceptance post-revision, we will not be able to consider it further for publication. Best of luck and we’ll look forward to receiving your revision shortly.

Comments to Author:

Reviewers’ Comments to Author:
Reviewer: 1

Comments to the Author(s)
This paper provides numerical results from the analysis of pipes pulled horizontally through sand. The flow in the manuscript is weak in places and important information required in a paper focusing on modeling is missing. There is a disproportionate emphasis at the beginning on the experimental programme that had been carried out previously and published elsewhere. Given the large end displacements, up to 30 mm, progressive failure would be expected, which cannot be properly accommodated by the constitutive model. Some specifics include:
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5. Page 6, line 58: What does the quadrilateral element response have to do with the triangular element response? In section 4.2 it was made clear that the 2-D, 6-node triangular element was used. There are ways of predicting softer responses with 3-node triangular elements.

6. Page 7, Line 39: Should likely be referring to Figure 12 not 11.

7. Section 5.5: Just because ASCE charts go up to a friction angle of 45, is not a good reason to use the residual strength for carrying out the analysis.

Reviewer: 2

Comments to the Author(s)
This paper presents experimental data and numerical simulations of tests investigating the behavior of buried steel pipelines subjected to lateral earth movement. The presented experimental data are useful for understanding pipeline behavior and for future numerical model calibration by other researchers. The presented numerical modeling, including the Janbu expression for the elastic modulus distribution with depth, is based on rather simple, standard procedures. The conclusions derived from the comparisons of the experimental measurements and the numerical results seem to be reasonable. Therefore, this reviewer recommends publication of the article.

Reviewer: 3

Comments to the Author(s)
The paper needs substantial improvement in terms of writing, analysis and presentation before publishing. Some points to consider are as below. Subroutine incorporated modelling shows improvement in prediction of pipe response. But, the paper needs improvement by highlighting the its main contribution and significance.

• Please highlight the significance of research work (such as need of incorporating stress dependent E value)
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• Please also compare peak load/(soil unit weight x height x diameter x length) as the guidelines are based on this scale.
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• Even with Janbu’s incorporation, there is substantial difference in peak load and mobilization in Fig. 17. Please discuss.
• It would be useful to propose analytical model for bending moment based on the numerical predictions using Janbu’s stress dependent formulation.

Author’s Response to Decision Letter for (RSOS-181550.R0)

See Appendix A.

RSOS-181550.R1 (Revision)

Review form: Reviewer 3

Is the manuscript scientifically sound in its present form?
Yes.

Are the interpretations and conclusions justified by the results?
Yes.

Is the language acceptable?
No.

Is it clear how to access all supporting data?
Not Applicable.

Do you have any ethical concerns with this paper?
No.

Have you any concerns about statistical analyses in this paper?
No.
Recommendation?
Accept with minor revision (please list in comments)

Comments to the Author(s)
Authors have adequately addressed my first round comments and hence I suggest accepting. However, the structure and presentation of the manuscript can be improved.

Decision letter (RSOS-181550.R1)

10-May-2019

Dear Dr Almahakeri:

On behalf of the Editors, I am pleased to inform you that your Manuscript RSOS-181550.R1 entitled "NUMERICAL TECHNIQUES FOR DESIGN CALCULATIONS OF LONGITUDINAL BENDING IN BURIED STEEL PIPES SUBJECTED TO LATERAL EARTH MOVEMENTS" has been accepted for publication in Royal Society Open Science subject to minor revision in accordance with the referee suggestions. Please find the referees' comments at the end of this email.

The reviewers and Subject Editor have recommended publication, but also suggest some minor revisions to your manuscript. Therefore, I invite you to respond to the comments and revise your manuscript.

- Ethics statement
If your study uses humans or animals please include details of the ethical approval received, including the name of the committee that granted approval. For human studies please also detail whether informed consent was obtained. For field studies on animals please include details of all permissions, licences and/or approvals granted to carry out the fieldwork.

- Data accessibility
It is a condition of publication that all supporting data are made available either as supplementary information or preferably in a suitable permanent repository. The data accessibility section should state where the article's supporting data can be accessed. This section should also include details, where possible of where to access other relevant research materials such as statistical tools, protocols, software etc can be accessed. If the data has been deposited in an external repository this section should list the database, accession number and link to the DOI for all data from the article that has been made publicly available. Data sets that have been deposited in an external repository and have a DOI should also be appropriately cited in the manuscript and included in the reference list.

If you wish to submit your supporting data or code to Dryad (http://datadryad.org/), or modify your current submission to dryad, please use the following link: http://datadryad.org/submit?journalID=RSOS&manu=RSOS-181550.R1

- Competing interests
Please declare any financial or non-financial competing interests, or state that you have no competing interests.
• Authors’ contributions
All submissions, other than those with a single author, must include an Authors’ Contributions section which individually lists the specific contribution of each author. The list of Authors should meet all of the following criteria; 1) substantial contributions to conception and design, or acquisition of data, or analysis and interpretation of data; 2) drafting the article or revising it critically for important intellectual content; and 3) final approval of the version to be published.

All contributors who do not meet all of these criteria should be included in the acknowledgements.

We suggest the following format:
AB carried out the molecular lab work, participated in data analysis, carried out sequence alignments, participated in the design of the study and drafted the manuscript; CD carried out the statistical analyses; EF collected field data; GH conceived of the study, designed the study, coordinated the study and helped draft the manuscript. All authors gave final approval for publication.

• Acknowledgements
Please acknowledge anyone who contributed to the study but did not meet the authorship criteria.

• Funding statement
Please list the source of funding for each author.

Please note that we cannot publish your manuscript without these end statements included. We have included a screenshot example of the end statements for reference. If you feel that a given heading is not relevant to your paper, please nevertheless include the heading and explicitly state that it is not relevant to your work.

Because the schedule for publication is very tight, it is a condition of publication that you submit the revised version of your manuscript before 19-May-2019. Please note that the revision deadline will expire at 00.00am on this date. If you do not think you will be able to meet this date please let me know immediately.

To revise your manuscript, log into https://mc.manuscriptcentral.com/rsos and enter your Author Centre, where you will find your manuscript title listed under “Manuscripts with Decisions”. Under "Actions," click on "Create a Revision." You will be unable to make your revisions on the originally submitted version of the manuscript. Instead, revise your manuscript and upload a new version through your Author Centre.

When submitting your revised manuscript, you will be able to respond to the comments made by the referees and upload a file "Response to Referees" in "Section 6 - File Upload". You can use this to document any changes you make to the original manuscript. In order to expedite the processing of the revised manuscript, please be as specific as possible in your response to the referees.

When uploading your revised files please make sure that you have:

1) A text file of the manuscript (tex, txt, rtf, docx or doc), references, tables (including captions) and figure captions. Do not upload a PDF as your "Main Document".
2) A separate electronic file of each figure (EPS or print-quality PDF preferred (either format should be produced directly from original creation package), or original software format)
3) Included a 100 word media summary of your paper when requested at submission. Please ensure you have entered correct contact details (email, institution and telephone) in your user account.

4) Included the raw data to support the claims made in your paper. You can either include your data as electronic supplementary material or upload to a repository and include the relevant doi within your manuscript.

5) All supplementary materials accompanying an accepted article will be treated as in their final form. Note that the Royal Society will neither edit nor typeset supplementary material and it will be hosted as provided. Please ensure that the supplementary material includes the paper details where possible (authors, article title, journal name).

Supplementary files will be published alongside the paper on the journal website and posted on the online figshare repository (https://figshare.com). The heading and legend provided for each supplementary file during the submission process will be used to create the figshare page, so please ensure these are accurate and informative so that your files can be found in searches. Files on figshare will be made available approximately one week before the accompanying article so that the supplementary material can be attributed a unique DOI.

Once again, thank you for submitting your manuscript to Royal Society Open Science and I look forward to receiving your revision. If you have any questions at all, please do not hesitate to get in touch.

Kind regards,
Andrew Dunn
Royal Society Open Science Editorial Office
Royal Society Open Science
openscience@royalsociety.org

on behalf of Prof R. Kerry Rowe (Subject Editor)
openscience@royalsociety.org

Associate Editor Comments to Author:
The reviewer considers the paper to be scientifically sound and ready for publication, but you should take another look at the paper's presentation before resubmitting, as it appears additional work to improve the clarity of presentation might be possible. Nevertheless, congratulations on this outcome!

Reviewer comments to Author:
Reviewer: 3

Comments to the Author(s)
Authors have adequately addressed my first round comments and hence I suggest accepting. However, the structure and presentation of the manuscript can be improved.

Author's Response to Decision Letter for (RSOS-181550.R1)

See Appendix B.
31-May-2019

Dear Dr Almahakeri,

I am pleased to inform you that your manuscript entitled "NUMERICAL TECHNIQUES FOR DESIGN CALCULATIONS OF LONGITUDINAL BENDING IN BURIED STEEL PIPES SUBJECTED TO LATERAL EARTH MOVEMENTS" is now accepted for publication in Royal Society Open Science.

You can expect to receive a proof of your article in the near future. Please contact the editorial office (openscience_proofs@royalsociety.org and openscience@royalsociety.org) to let us know if you are likely to be away from e-mail contact. Due to rapid publication and an extremely tight schedule, if comments are not received, your paper may experience a delay in publication.

Royal Society Open Science operates under a continuous publication model (http://bit.ly/cpFAQ). Your article will be published straight into the next open issue and this will be the final version of the paper. As such, it can be cited immediately by other researchers. As the issue version of your paper will be the only version to be published I would advise you to check your proofs thoroughly as changes cannot be made once the paper is published.

On behalf of the Editors of Royal Society Open Science, we look forward to your continued contributions to the Journal.

Kind regards,
Andrew Dunn
Royal Society Open Science Editorial Office
Royal Society Open Science
openscience@royalsociety.org

on behalf of Prof R. Kerry Rowe (Subject Editor)
openscience@royalsociety.org

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https://www.facebook.com/RoyalSocietyPublishing.FanPage/
Read Royal Society Publishing's blog: https://blogs.royalsociety.org/publishing/
Reviewer-1

1. Comments to the Author(s)

This paper provides numerical results from the analysis of pipes pulled horizontally through sand. The flow in the manuscript is weak in places and important information required in a paper focusing on modeling is missing. There is a disproportionate emphasis at the beginning on the experimental programme that had been carried out previously and published elsewhere. Given the large end displacements, up to 30 mm, progressive failure would be expected, which cannot be properly accommodated by the constitutive model. Some specifics include:

The English must be improved. In some places it is awkward, there are spelling mistakes and inappropriate words or grammatical tense are used. Take for example, the third sentence in the introduction. “Soil instability may be considered a soil failure but soil creep is a mechanism”.

** Thank you for taking the time to review this manuscript. It is very much appreciated!**

Authors have reviewed the first three sentences of the introduction (shown below) and could not find the incorrect sentence that is being referred to in the comment. A comprehensive review of the manuscript has been conducted and many improvements have been introduced to the manuscript in general.

“Oil and gas transmission lines can cross zones of soil instability and may need to be designed to resist differential ground movements. Soil instabilities can result from natural phenomena such as soil creep, slope failures, landslides, and earthquake-induced faults. Other man-made activities can lead to lateral soil movements against pipes such as excavation, tunneling, directional drilling, and pipe bursting”

2. Also referring to 5 lines down from the top of page 2 the word focused should probably be replaced by focusing.

** “focused” has been changed to “focusing”.**

3. On page 2, line 30: analyses is spelt incorrectly.

** Authors used the plural form of the word not the singular in referral to a class of 3D-FEA analyses that are often encountered when using lower-order elements. Upon further review and considering the reviewer’s feedback on the readability of the sentence, the word has now changed to the singular form “analysis”.

4. Figure 9 appears to be referred to before Figure 8.

** The reason is that Figure 9 is the first figure where the method of determining the pipe displacement at peak pulling load, $Y_u$, could be illustrated. Also, it was necessary to present the concept of $P_u-Y_u$ relation before discussing Figure 8. To clear up any confusion this may cause to the reader, the sentence has been modified as follows (Lines 266-267):**
“An illustration of how peak pulling force $P_u$ values corresponding to $Y_{ue}$ are extracted from three different numerical analyses appears in a subsequent figure (Figure 9), for embedment ratio of $H/D=3$.”

5. It is clear from the introduction that the paper focuses on analysis, yet section 2 provides a disproportionate amount of information on the “Testing Program”. From a numerical analysis point of view, it would have been sufficient to show the basic layout of the test being analyzed (not the facility) and the properties of the soil, including a figure of a typical stress-strain response of the sand.

** The “Testing Facility” sub-section has been removed and the “Testing Program” section has been rewritten to provide a more concise description of the experimental work. Also, in addition to the experimental data (Load-Displacement curve) that depict the stress-strain behaviour of dense sand, a reference for additional details of the soil characterization tests including grain size analysis, and triaxial tests have been included in this section. It reads (Line 59):

“Details of the soil characterization tests including grain size analysis, and triaxial tests are discussed by Almahakeri [25].”

6. Had the sand been dense, it would probably have undergone post-peak softening that would have included shear banding. For such a case a constant dilation angle would have been inappropriate and local progressive failure would have taken place before the peak load would have been reached that reflects a macro-scale measure. The reviewer is aware that only the behavior up to peak was of interest.

** Authors do agree with the reviewer’s comment on dense sand behavior. As one of the main objectives of the current study (stated in Lines 40-41) is to develop a simple3D modeling technique to estimate the load-deflection response of pipes moving laterally through the ground, based on independent parameters for the pipe and soil. This is achieved by describing a simple stress-dependent soil modulus -up to peak loading- using a built-in “utility” subroutine (by employing the Janbu model) and comparing it against different experimental results. Other, more sophisticated, full material user-defined, subroutines are more robust, but often not available in the public domain. The model presented in the current study, which has been verified against different experimental results can be of direct benefit to both researchers and industry practitioners alike. Authors can reflect this idea in the text if deemed necessary.
7. The reviewer appreciates that a commercial code was used and that low-order elements are favoured for problems involving contact and large displacements. Were the stress and strain rate measures objective? Also, the 3-D 8-node element is known to have problems if bending modes are present, say adjacent to the pipe. Was selective (not reduced) integration used to improve the performance of the 8-node element?

** ABAQUS software does incorporate the use of “selective Integration” formulation for its 8-noded linear hexahedral elements (C3D8) formulation.

8. Page 6, line 58: What does the quadrilateral element response have to do with the triangular element response? In section 4.2 it was made clear that the 2-D, 6-node triangular element was used. There are ways of predicting softer responses with 3-node triangular elements.

** Upon review, the two sentences relevant to the quadrilateral elements behavior and the reference to the work by Sloan (1983) does not apply to the work presented in this manuscript since all 2D analyses have been executed using the triangle elements (as indicated in section 4.2). While attempts of using quadrilateral elements were made (discussed briefly in the original submission-section 4.2, Lines 168-169), no detailed results were reported. Hence, the following two sentences have been removed from the manuscript.

“Sloan [36] explains that quadrilateral elements are known to be over stiff when used with full integration, and that oscillations can arise when using reduced integration to counter those problems. Sloan indicates that this influences both drained behavior (where there is frictional behaviour and volume change) and undrained analysis (where friction angle is zero and volume change should be zero”

9. Page 7, Line 39: Should likely be referring to Figure 12 not 11.

** Corrected.

10. Section 5.5: Just because ASCE charts go up to a friction angle of 45, is not a good reason to use the residual strength for carrying out the analysis.

** The reason ASCE soil capacity limits were calculated based on the constant volume friction angle ($\phi_{\text{resid}} = 45^\circ$) instead of peak friction angle ($\phi_p = 53^\circ$) is to ensure direct comparison between the two methods. As no peak loads could be extracted from ASCE guidelines for critical friction angle of 53°, authors
compared the ASCE using $\phi_{\text{resid}}$ with the residual strength of the soil—not the peak load—as shown in Figure 14.

A clarification has been introduced in the text as follows (Lines 382-384):

“In order to ensure direct comparison between the two methods, the ASCE guidelines residual strength estimations were compared to the residual strength of the soil as illustrated in Figure 14.”

***Thank you for your time and valuable feedback!

**Reviewer: 2**

Comments to the Author(s)

This paper presents experimental data and numerical simulations of tests investigating the behavior of buried steel pipelines subjected to lateral earth movement. The presented experimental data are useful for understanding pipeline behavior and for future numerical model calibration by other researchers. The presented numerical modeling, including the Janbu expression for the elastic modulus distribution with depth, is based on rather simple, standard procedures. The conclusions derived from the comparisons of the experimental measurements and the numerical results seem to be reasonable. Therefore, this reviewer recommends publication of the article.

**Thank you for taking the time to review this manuscript. It is very much appreciated!**
Reviewer: 3

Comments to the Author(s)

The paper needs substantial improvement in terms of writing, analysis and presentation before publishing. Some points to consider are as below. Subroutine incorporated modelling shows improvement in prediction of pipe response. But, the paper needs improvement by highlighting the its main contribution and significance.

** Thank you for taking the time to review this manuscript. It is very much appreciated!

1. Please highlight the significance of research work (such as need of incorporating stress dependent E value)

*** An introductory sentence has been added at the start of the literature review section (Line 1, third paragraph) and another one at the end of the section (Line 19) to highlight the significance and focus of the current study on the use of stress-dependant model to the soil stress-strain relation. Both sentences are shown below:

“In pipe-soil interaction problems, it is known that the soil stress-strain relation governs the restraint loads imposed on the pipeline. Over the years, many models have been developed to capture the influence of different parameters of the soil.

. . . Section on literature review goes here . .

In the present study, simple 2D and 3D finite element models employing stress-dependent stiffness of the soil using Janbu model subroutine are presented and discussed.”

2. Line 46 p.1; it would be appropriate to use third person language in the manuscript

*** Three relative pronouns (“who”) were identified and removed from the text.

3. Line 35 p.2: Please add more description of the tests; such as soil condition, soil type, etc

*** In consideration for Reviewer #1 suggestion to keep some appropriation of the size of the description of the experimental work (by reducing it) and to address the current comment, authors have cited an additional reference for readers to get more details about the testing program. Additionally, basic soil conditions and parameters (dry Olivine dense sand, with friction angle, dilation angle, density, and modulus of elasticity distribution) have been reported in the manuscript. Authors can provide any other specific information related to the soil related to the study.
For cohesion, c, since the Mohr–Coulomb model implemented in ABAQUS requires nonzero cohesion to accommodate the shape of flow potential close to the apex of the model, a minimum value of 1 kPa was employed even though the test sand was dry. This artificial cohesion was introduced to ensure the soil had a small but non-zero strength when in a state of zero confining stress. This is a common requirement reported in many other studies [3,30,31].

Reference has been added to text.

Additional information has been added to indicate the element size (Line 189), and node seeding approach used in the finite element models [Line 183]. Also, additional figures (Figure 4a,b,c,d,e, and f) showing the different meshes used for the analyses (2D & 3D) along with the corresponding number of nodes and elements have been added.

Authors reviewed section 4.5 and there was no mention about load-displacement curves. The section primarily discusses the method used to define pipe displacement at peak pulling load ($Y_u$). If the comment is regarding $Y_u$, both Figure 6 and Figure 7 include comparison with the experiments. For load-displacement curves, Figures 9, 11, 13, and 14 compare the different model calculations to the experimental results.

Authors reported peak loads (per unit length of the pipe) to maintain consistency with the other load-displacement figures in the manuscript. A clarification has been included in the text to indicate that load-displacement curves in Figure 14 (experimental and numerical) are compared to
corresponding values (i.e., pulling load/unit length) using the ASCE (1984) guidelines. New text now reads (Lines 379-380):

"Measured and calculated values for $P_u$ reported in this study are now compared with the corresponding values using ASCE guidelines [20] based on the work of Trautmann and O'Rourke [22]."

9. Results and discussion section has not been written well. It needs improvement in terms of presentation and rigorous analysis.

Authors assume that the revised manuscript has now sufficient analysis and clarification.

10. Would pipe pulling load same as pipe lateral load?

Yes, it is the same load as pulling displacement was applied at the pipe end nodes (where reaction forces were calculated). A clarification has been added to the text. Lines (229-230) now read:

"The calculated pulling load on the pipe was extracted from the reaction forces of the pipe end nodes where prescribed displacement was applied."

11. It is clear from literature that plane strain and structured elements are the most suitable element type for this problem (lateral pipeline analysis). I am not sure why authors want to present this parametric study on element types? It appears not significant to present in the paper.

*** Plane strain elements have been used in the current study as indicated in section 5.2 (Line 166). The use of the automatic built-in mesh generation of the software was employed as the structured mesh configuration encountered numerical instability for the CPE6M elements. However, there was a negligible difference between the two different mesh configurations over the completed part of the analysis. The above comment has been addressed in the text. Lines (185-187) now read:

"The automatic built-in mesh generation of the software was employed as structured mesh configuration encountered numerical instability for the CPE6M elements (analysis aborted at 10.3% of completion. Comparison of the load-displacement curve between the two mesh configurations over the completed part of the analysis showed almost identical behavior."
12. Why there is a substantial difference between tests and 3-D numerical model predictions in Fig 14. The explanation was provided in the original manuscript (now lines 371-376)

13. Even with Janbu’s incorporation, there is substantial difference in peak load and mobilization in Fig. 17. Please discuss

Figure 17 is the comparison between the calculated load-displacement curve using Janbu model and the one using uniform soil modulus. The Janbu model curve (shown in Figure 17) was first introduced and discussed in an earlier section. It was also compared to experimental data (Figure 9). It is worth noting also that peak loading was determined using the $Y_u$ discussed in section 4.5. and hence, Janbu model showed very good agreement at the burial test illustrated in Figure 17.

14. It would be useful to propose analytical model for bending moment based on the numerical predictions using Janbu’s stress dependent formulation

Thank you for the suggestion. This definitely is an excellent topic for future work authors can explore in future work.

***Thank you for your time and valuable feedback!***
Appendix B

June 25, 2019

Editor

Royal Open Society

Dear Editor:

RE: Numerical Techniques for Design Calculations of Longitudinal Bending in Buried Steel Pipes Subjected to Lateral Earth Movements by Mohamed Almahakeri, Ian D. Moore, and Amir Fam

Please find enclosed a revised manuscript with additional improvements to the presentation of the paper.

We’d like to thank you and all the reviewers for the time and efforts and look forward to seeing the paper in print.

Yours sincerely,

Mohamed Almahakeri