

BACHELORS DEGREE ASSIGNMENT SPECIFICATION

Student name:	ANDERSON	Student P number:	
Programme:	BEng Automotive and Manufacturing streams		
Module:	Advanced Stress Analysis & FEA	Module Level (4, 5, 6):	6
Module code:	M6X00420	Contribution to Overall Module Assessment (%):	50 %
Lecturer:	Kelvin Lake	Internal Verifier:	Rob Goodson
Assignment Title:	Can FEA replace physical testing?	Assignment No (x of x):	1 OF 1
Hand Out Date:	25/02/2020	Submission deadline:	29/03/2020

Referencing:	In the main body of your submission you must give credit to authors on whose research your work is based. Append to your submission a reference list that indicates the books, articles, etc. that you have read or quoted in order to complete this assignment (e.g. for books: surname of author and initials, year of publication, <u>title of book</u> , edition, publisher: place of publication).			
Disclosure:	I declare that this assignment is all my own work and that I have acknowledged all materials used from the published or unpublished works of other people. All references have been duly cited.			
Student's Signature:	<i>Assignments will not be accepted without a signature here</i>	Date:		
Turnitin: Lecturer to tick to indicate if an electronic version of the assignment must be submitted to Turnitin. Note: the Turnitin version is the primary submission and acts as a receipt for the student. Penalties for late submission: Up to four weeks late, maximum mark of 40%. Over four weeks late, Refer. Only Year Tutors and the Programme Director may grant an extension.			YES	✓
			NO	

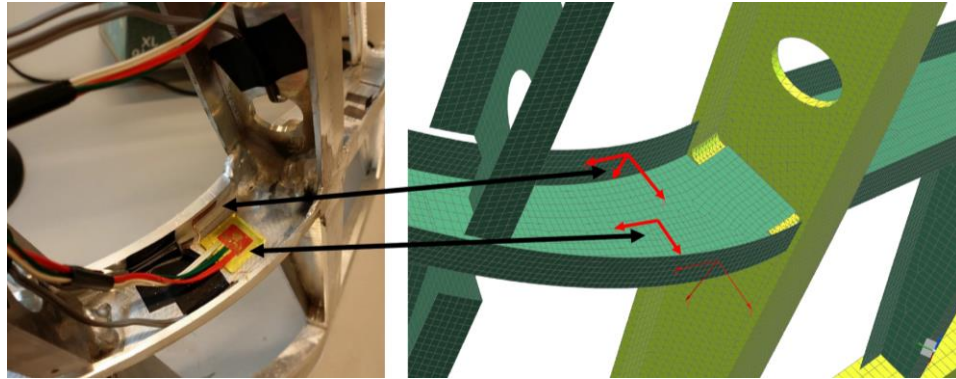
Learning Outcomes tested (from module syllabus)	Assessment Criteria To achieve each outcome a student must demonstrate the ability to:
Demonstrate an ability to analyse a range of engineering problems using advanced stress analysis principles.	

- DO NOT put this form into Turnitin or it will match many similarities with other students' submissions.

TASK DESCRIPTION

This assignment explores FEA and the role that it plays in product development. It is expected that the student will research this topic (referencing any sources used, using Harvard or Vancouver).

GUIDANCE FOR STUDENTS IN THE COMPLETION OF TASKS



The above image shows a component undergoing physical testing and the corresponding FE model. Your task for this assignment is to discuss the following;

1. Why companies typically carryout FE analysis alongside physical testing.
2. How a physical test may be correlated to an FE model.
3. If you think that FE analysis can (or should) ever replace physical testing.

In order to do this, you should consider a case study and use this to discuss the above tasks.

This report should be 3000 words long and should be submitted via moodle

STRUCTURAL SECTION MARKING CRITERIA AND STUDENT FEEDBACK

This section details the assessment criteria. The *extent* to which these are demonstrated by you determines your mark. The marks available for each criterion are shown. Lecturers will use the space provided to comment on the achievement of the task(s), including those areas in which you have performed well and areas that would benefit from development/improvement.

Common Assessment Criteria Applied	Marks available	Marks awarded
1. Research-informed Literature Extent of research and/or own reading, selection of credible sources, application of appropriate referencing conventions.		
(Assessed in point 1)	30	19.5
2. Knowledge and Understanding of Subject Extent of knowledge and understanding of concepts and underlying principles associated with the discipline.		
(Assessed in point 2)	30	18.9
3. Analysis Analysis, evaluation and synthesis; logic, argument and judgement; analytical reflection; organisation of ideas and evidence		
(N/A)	0	
4. Practical Application and Deployment Deployment of methods, materials, tools and techniques; application of concepts; formulation of innovative and creative solutions to solve problems.		
(Assessed in point 3)	30	20.1
5. Skills for Professional Practice Attributes in professional practice: individual and collaborative working; deployment of appropriate media; presentation and organisation.		
(Assessed in report presentation and structure)	10	6.5

Assignment Mark Overall (Assessment marks are subject to ratification at the Exam Board. These comments and marks are to give feedback on module work and are for guidance only until they are confirmed.)	Late Submission Penalties (tick if appropriate)		65 %
	Up to one-week late		
	Over one week late		

COMMON ASSESSMENT AND MARKING CRITERIA

	OUTRIGHT FAIL	UNSATISFACTORY	SATISFACTORY	GOOD	VERY GOOD	EXCELLENT	EXCEPTIONAL
Assessment Criteria	0-29%	30-39%*	40-49%	50-59%	60-69%	70-79%	80-100%
1. Research-informed Literature Extent of research and/or own reading, selection of credible sources, application of appropriate referencing conventions	Little or no evidence of reading. Views and findings unsupported and non-authoritative. Referencing conventions largely ignored.	Poor evidence of reading and/or of reliance on inappropriate sources, and/or indiscriminate use of sources. Referencing conventions used inconsistently.	References to a limited range of mostly relevant sources. Some omissions and minor errors. Referencing conventions evident though not always applied consistently.	Inclusion of a range of research-informed literature, including sources retrieved independently. Referencing conventions mostly consistently applied.	Inclusion of a wide range of research-informed literature, including sources retrieved independently. Selection of relevant and credible sources. Very good use of referencing conventions, consistently applied.	A comprehensive range of research informed literature embedded in the work. Excellent selection of relevant and credible sources. High-level referencing skills, consistently applied.	Outstanding knowledge of research-informed literature embedded in the work. Outstanding selection of relevant and credible sources. High-level referencing skills consistently and professionally applied.
2. Knowledge and Understanding of Subject Extent of knowledge and understanding of concepts and underlying principles associated with the discipline.	Major gaps in knowledge and understanding of material at this level. Substantial inaccuracies.	Gaps in knowledge, with only superficial understanding. Some significant inaccuracies.	Evidence of basic knowledge and understanding of the relevant concepts and underlying principles.	Knowledge is accurate with a good understanding of the field of study.	Knowledge is extensive. Exhibits understanding of the breadth and depth of established views.	Excellent knowledge and understanding of the main concepts and key theories. Clear awareness of challenges to established views and the limitations of the knowledge base.	Highly detailed knowledge and understanding of the main theories/concepts, and a critical awareness of the ambiguities and limitations of knowledge.
3. Analysis Analysis, evaluation and synthesis; logic, argument and judgement; analytical reflection; organisation of ideas and evidence	Unsubstantiated generalisations, made without use of any credible evidence. Lack of logic, leading to unsupportable/missing conclusions. Lack of any attempt to analyse, synthesise or evaluate.	Some evidence of analytical intellectual skills, but for the most part descriptive. Ideas/findings sometimes illogical and contradictory. Generalised statements made with scant evidence. Conclusions lack relevance.	Evidence of some logical, analytical thinking and some attempts to synthesise, albeit with some weaknesses. Some evidence to support findings/ views, but evidence not consistently interpreted. Some relevant conclusions and recommendations, where relevant	Evidence of some logical, analytical thinking and synthesis. Can analyse new and/or abstract data and situations without guidance. An emerging awareness of different stances and ability to use evidence to support the argument. Valid conclusions and recommendations, where relevant	Sound, logical, analytical thinking; synthesis and evaluation. Ability to devise and sustain persuasive arguments, and to review the reliability, validity & significance of evidence. Ability to communicate ideas and evidence accurately and convincingly. Sound, convincing conclusions / recommendations.	Thoroughly logical work, supported by evaluated evidence. High quality analysis, developed independently or through effective collaboration. Ability to investigate contradictory information and identify reasons for contradictions. Strong, persuasive, conclusions, justifiable recommendations.	Exceptional work; judiciously selected and evaluated evidence. Very high quality analysis, developed independently or through effective collaboration. Ability to investigate contradictory information and identify reasons for contradictions. Highly persuasive conclusions
4. Practical Application and Deployment Effective deployment of appropriate methods, materials, tools and techniques; extent of skill demonstrated in the application of concepts to a variety of processes and/or contexts; formulation of innovative and creative solutions to solve problems.	Limited or no use of methods, materials, tools and/or techniques. Little or no appreciation of the context of the application.	Rudimentary application of methods, materials, tools and/or techniques but without consideration and competence. Flawed appreciation of the context of the application.	An adequate awareness and mostly appropriate application of well established methods, materials, tools and/or techniques. Basic appreciation of the context of the application.	A good and appropriate application of standard methods, materials, tools and/or techniques. Good appreciation of the context of the application, with some use of examples, where relevant.	A very good application of a range of methods, materials, tools and/or techniques. Very good consideration of the context of the application, with perceptive use of examples, where relevant. Evidence of some innovation and creativity.	An advanced application of a range of methods, materials, tools and/or techniques. The context of the application is well considered, with extensive use of relevant examples. Application and deployment extend beyond established conventions. Innovation and creativity evident throughout.	Outstanding levels of application and deployment skills. Assimilation and development of cutting edge processes and techniques.
5. Skills for Professional Practice Demonstrates attributes expected in professional practice including: individual initiative and collaborative working; deployment of appropriate media to communicate (including written and oral); clarity and effectiveness in presentation and organisation.	Communication media is inappropriate or misapplied. Little or no evidence of autonomy in the completion of tasks. Work is poorly structured and/or largely incoherent.	Media is poorly designed and/or not suitable for the audience. Poor independent or collaborative initiative. Work lacks structure, organisation, and/or coherence	Can communicate in a suitable format but with some room for improvement. Can work as part of a team, but with limited involvement in group activities. Work lacks coherence in places and could be better structured.	Can communicate effectively in a suitable format, but may have minor errors. Can work effectively as part of a team, with clear contribution to group activities. Mostly coherent work and is in a suitable structure.	Can communicate well, confidently and consistently in a suitable format. Can work very well as part of a team, with very good contribution to group activities. Work is coherent and fluent and is well structured and organised.	Can communicate professionally and, confidently in a suitable format. Can work professionally within a team, showing leadership skills as appropriate, managing conflict and meeting obligations. Work is coherent, very fluent and is presented professionally.	Can communicate with an exceptionally high level of professionalism. Can work exceptionally well and professionally within a team, showing advanced leadership skills. Work is exceptionally coherent, very fluent and is presented professionally.

Student Self Evaluation Form

Student name:		Student P number:	
Programme:		Year of programme	
Assignment Title:			

This section repeats in brief the common assessment criteria detailed on previous pages. The *extent* to which these are demonstrated by you determines your mark. Using these criteria, tick the box that best indicates the level of achievement you feel you have achieved with regard to each of them.

Common Assessment Criteria Applied	Level of Achievement						
	REFER		3 rd	2:2	2:1	1 st	1 st
	OUTRIGHT FAIL	UNSATISFACTORY	SATISFACTORY	GOOD	VERY GOOD	EXCELLENT	EXCEPTIONAL
1. Research-informed Literature	0-29% ☐	30-39% ☐	40-49% ☐	50-59% ☐	60-69% ☐	70-79% ☐	80-100% ☐
2. Knowledge and Understanding of Subject	0-29% ☐	30-39% ☐	40-49% ☐	50-59% ☐	60-69% ☐	70-79% ☐	80-100% ☐
3. Analysis	0-29% ☐	30-39% ☐	40-49% ☐	50-59% ☐	60-69% ☐	70-79% ☐	80-100% ☐
4. Practical Application and Deployment	0-29% ☐	30-39% ☐	40-49% ☐	50-59% ☐	60-69% ☐	70-79% ☐	80-100% ☐
5. Skills for Professional Practice	0-29% ☐	30-39% ☐	40-49% ☐	50-59% ☐	60-69% ☐	70-79% ☐	80-100% ☐

PLEASE COMMENT ON AREAS IN WHICH YOU FEEL THAT YOU HAVE PERFORMED WELL	PLEASE COMMENT ON AREAS YOU FEEL THAT YOU NEED TO DEVELOP

Student's Name		Date	
Student's Signature			



University of Wales Trinity Saint David
School of Engineering

Can FEA Replace Physical Testing

Michael Anderson

P151178

31/03/20

Advanced Stress Analysis & FEA

M6X00420

Kelvin Lake

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1) Introduction

This report will cover the basic principles of FEA and how it relates to physical testing within the real world.

Research was conducted into both FEA and physical testing to determine how effective each method is at displaying any deformations that would occur on a component under load. This led into uncovering why companies use FEA software alongside physical testing during the design process.

An important aspect of any virtual simulation is the ability to replicate results that would be seen within real life. If this correlation does not occur, the results predicted by the FEA software package could not be trusted as their validity would be in question.

Although the advantages of FEA programs are substantial, there are just as many negatives, or at least potentially, as there are positives. These will be discussed and compared to each other to answer the question if FEA could completely replace physical testing experiments, to ascertain the quality, strengths and weaknesses of a component.

2) FEA vs Physical Testing

2.1. Why Companies Typically Carryout FEA Alongside Physical Testing.

Physical testing has been conducted since the beginning of invention. Every time a product is created, it has always been necessary to test its operation within real-world conditions, before selling the product to a customer. This allows the designer to ensure their product works as intended, whether due to structural requirements, safety concerns or determining if new materials or methods of assembly/manufacturing have adversely affected the overall quality and performance of the finalised product.

Although the results of physical testing can be accurate, it is hard to maintain an environment in which testing can occur without negative impacts to avoid adverse influences and untrustworthy results. For example, if during the products real world operation, it is only subjected to high ambient temperatures ($\sim 45^{\circ}\text{C}$) and dry conditions, then it would be highly impractical to test the durability of that product in an environment that does not reflect those conditions, e.g. where during testing the temperature is 0°C and it is submerged in water. The results would not reflect real-life values, trends or deterioration through wear, and would therefore be considered inaccurate, impractical and useless.

*TRUE. BUT A LONG WAY
OF MAKING THIS POINT.*

It can be expensive to create the correct environment for testing, whether due to replicating real-world conditions, such as wind speeds, temperature and pressure. The size of the facility would also drastically affect costing. Testing the yield strength of a bolt requires significantly less space and resources than applying the same testing method onto a fully assembled aeroplane wing, and should that test be conducted incorrectly, the bolt, and associated shrapnel, would be easier to contain than if the plane's wing collapsed due to inappropriate/inadequate joining methods (bolts/welds).

Since physical testing can be costly, Finite Element Analysis (FEA) computer software has been developed by numerous companies to mathematically simulate physical phenomenon, such as; compression, tension, instantaneous impacts or loading, on any object or shape, within a virtual environment using the numerical Finite Element Method (FEM) technique. Designers and Engineers alike, use FEA to reduce the number of physical prototypes created and experiments required to optimize components while being designed, to enhance the development of products quicker in comparison and more cost effective. (Simscale, 2020)

Mathematics are necessary to comprehensively understand and validate any physical phenomena that would occur within the component or assembly, during its lifetime. Most FEM processes split the geometric shape down into smaller pieces called elements, a parameter value defined by the user. Partial differential equations are applied to each individual element within the structure to determine the stress, strain, temperature or any other required data at any given time. Numerical techniques have been developed for use within this process to aid with the reduction in computational calculation time and processing power usage. (Caliber Design, 2015)

The advantages of using an FEA process are numerous (Pre Technologies, 2020):

- Generation of the physical response of the system, usually colour mapped to display stress concentrations or weak/break points for easier visualisation.
- Safe simulation of potentially hazardous, destructive or impractical loading conditions, reducing the need for a secure environment that would potentially need decontamination.
- Accessibility of running several physical events applied to the same model that would otherwise require a complicated 'jig' to secure the part or method of force application to simulate.
- The simultaneous calculation and visual representation of physical parameters and material characteristics, enabling the designer to analyse performance and apply modifications to compensate for unusual results or unexpected failures.
- Relatively low initial investment and calculation time compared to creating the environment to adequately test a physical prototype.

By using both FEA and physical testing on a product, both results can either validate or dispute one another. Should both set of results be within tolerance, they can confirm that the adverse effects that were observed in the virtual environment, would be replicated within real-life, **Figure 1**. They can just as easily oppose one another, in which case, it may be best to reconduct either one or both experiments.

The computational FEA result may be producing the expected outcome, but within the physical component, the materials used may have an undetected deformity, such as; rust, air pockets, microfractures or a slight change in alloy grade/composition of the material that cannot be seen without specialist procedures. On the other hand, the physical results could be correct, the FEA model may have been using an incorrect solver model, too small/large element size, incorrect material, density and mass applied to the component, which all would drastically change the results and their validity.

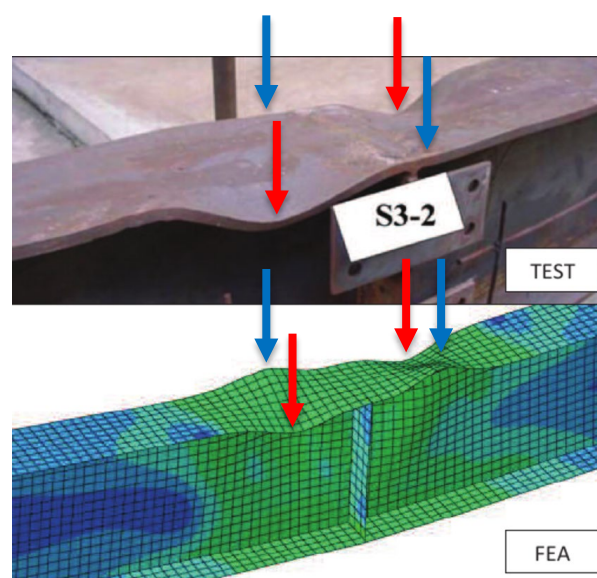
2.2. How A Physical Test May Be Correlated To An FE Model.

It is an indisputable fact that for FEA results to be comparable predictions to those of real-life, they must have some form of correlation, either in trends or values. It boils down to the fact that it is hard for FEA programs to predict exact real-life environments and situations, depending on the settings and solvers used. It generally predicts a static 'best case' scenario for the components at any one time.

Although software exists to create a simulation in motion, it is difficult to replicate a dynamically changing environment, subjecting the component to changes of temperature, pressure, lubrication, wind speed, rain and the sun. If the part is used outside in all weathers, it may be difficult to account for material degradation and deformation over time, including whether maintenance is not performed by the user at its allocated scheduling as stated by the manufacturer.

Designers use FEA primarily to test whether the component would withstand certain loadings, temperatures or pressures as if product was brand new, this allows them to determine whether the shaping or design was adequate for use at the point of sale, or needed revisiting. (Donald, 2007)

Figure 1 shows the different resultant outcomes from performing a buckling test upon an 'I' beam in the both the real world and using a FEA software package (Quan, et al., 2015). Overall there are similarities between the two, the highlighted red points show the similarities and the blue points show the differences.



GOOD
EXAMPLE

Figure 1 – Physical Testing vs FEA Model Comparison Under Buckling (Quan, et al., 2015)

It is then customary to provide every component with some form of guarantee or warranty period, ensuring the product will last a suitable lifetime, entirely dependent of the components use. E.g. a large 'I' beam for structural use within a building, should be designed to last a lot longer than a motorcycle brake lever, due to both the magnitude of the forces applied through the component, but also to a lack of accessibility, the cost of replacement parts or the ability for repairs to take place. (Vermaas & Vial, 2018)

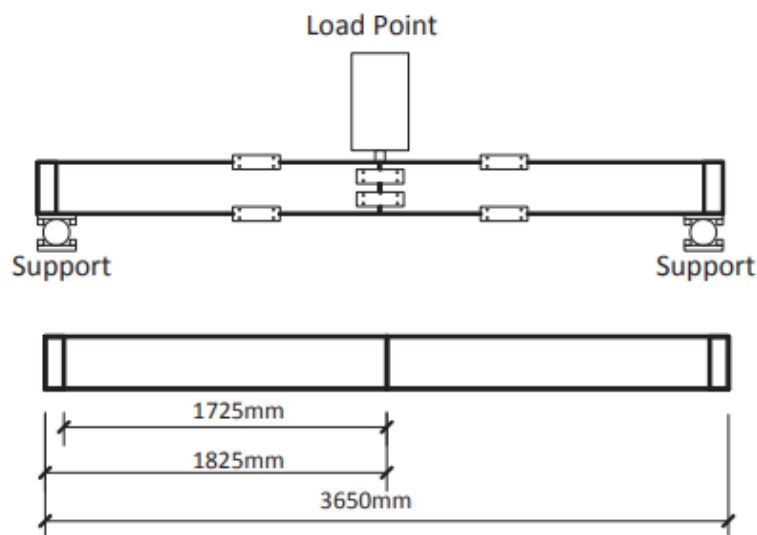


Figure 2 – Loading Of 'I' Beams (Quan, et al., 2015)

Both 'I' beams were laid horizontally while supported at both ends, then loaded in the centre and tested up to failure, **Figure 2**. This method was used to determine the strength of the beam-to-column connections trying different web thicknesses at different temperatures 415°C-615°C.

“This may be because the accuracy of the assumption of flange buckling length from Eq. (1) may differ at different temperatures; this would have a significant effect on the beam post-buckling behaviour.” (Quan, et al., 2015)

For this study, the ABAQUS software was used with an element size of 15mm by 15mm was used as an optimum balance between accuracy and computing efficiency.

It is clear to see they acknowledge that within the steel beam assembly, the 'I' beams are not the weak point, it is what joins the numerous beams together which is the weak link that would cause structural failure. Which, could result in criminal liability, should someone become injured after the component was installed, while being within its warranty period.

Figure 3 are the measurements from the experiments conducted on the physical 'I' beam sections, taken from the top and bottom flange breadths and thicknesses. "Table 4 presents the details of cross-section dimensions and test temperatures. All dimensions are the average values of measurements by Dharma [26] from different locations." (Quan, et al., 2015)

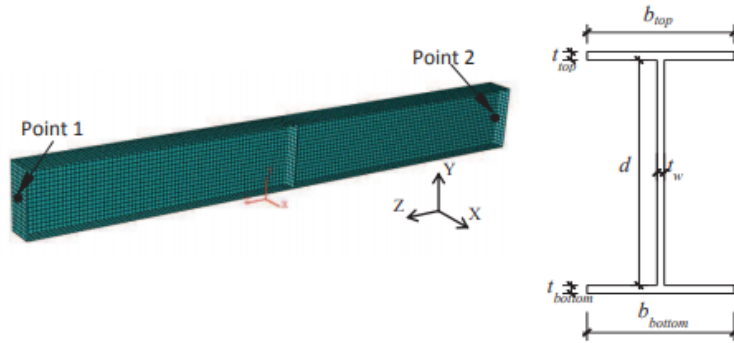


Fig. 18. Finite element model. (a) Image of finite element model; (b) cross section dimensions (in mm).

Table 4. Measured cross-section dimensions (in mm) and test temperature (in °C)

Test No.	b_{top}	b_{bottom}	t_{top}	t_{bottom}	d	t_w	T
S3-2	162.89	163.51	10.00	9.95	275.5	8.14	415
S3-3	162.72	164.00	10.30	10.19	275.93	7.95	615
S4-1	176.70	178.26	10.08	10.46	380.76	7.83	415
S4-2	177.83	176.71	10.29	10.52	380.78	7.76	615

A comparison between the FE modelling and experimental results is shown in Fig. 19.

Figure 3 – Measurements From The 'I' Beams Used For Physical Testing (Quan, et al., 2015)

During this study, they discovered that the FEA models can also predict the buckling shape very well compared with the physical test results; shown in Figure 1. Hence, the numerical model is considered reliable and was used within the study.

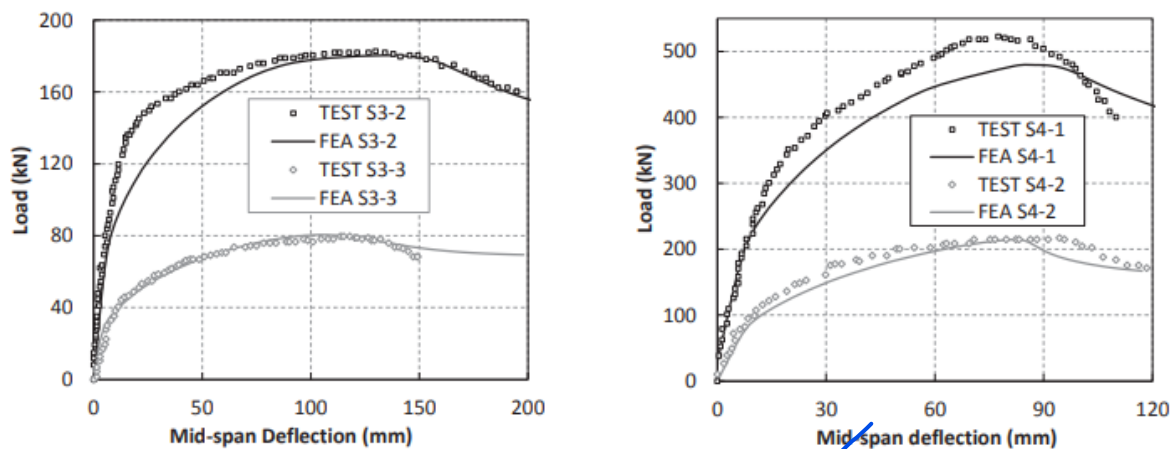


Figure 4 – Comparisons Between FEA & Real-World Results On Four Different Sections Of An 'I' Beam (Quan, et al., 2015)

2.3. Can (Or Should) FEA Ever Replace Physical Testing.

This question poses a difficult and unclear response. Physical testing should always take place and can never be ruled out completely. Because there's no better guarantee that a component will handle the stress and strains or be durable enough to last its designated lifetime, unless it is tested in the real world. This would allow extra tests to be conducted on the components afterwards, if the part becomes distorted, NDT processes would allow designers to understand how far away the part was from failing and where that failure would occur. If the part had failed, data could be collected to analyse the design and acknowledge areas where it can be improved upon. (Mayes, 2008)

FEA will always improve results and reduce the number of physical experiments required to take place by accurately predicting the results that would be expected, but nothing quite compares to the real thing. It has always been in a company's best interest to keep research and development costs low, making it easier to reclaim that cost back through sales. Depending on the size of the end product, it may be cheaper to run a multitude of FEA simulations compared to one physical test, but without that physical test taking place, how can you correlate the FEA results and predictions to those that would actually occur, even over time. (Ostergaard, 2018)

"[Digital] simulation has definitely come a long way from its initial applications in linear, structural analysis. Today, complex nonlinear structural analysis is commonplace ... the other area where it has grown is in fluid dynamics." (Wong, 2010)

By using FEA, we get an approximate solution based on numerous mathematical models that are available by using computer simulations. But relying totally on FEM is not the correct approach. As experimental techniques related to the study take place, it may be noticed that parameters used within the mathematical model are not accurate, bringing the validity of all previous studies using the old parameters into question. (Jamaludin, 2012)

In this case, it is necessary to modify the mathematical model and rerun the simulations and assess the impact those modification had on the data. By doing a series of experimental work, it is possible to modify the model and be able to predict the behaviour more accurately and closer to values exhibited in real-life. This can be highly advantageous as opposed to testing the component in a physical environment, due to its significant cost and impracticality. (ATA Engineering, 2020)

An experienced designer should not blindly follow a prediction of responses by the mathematical model. Should an FEA model be as accurate as real life, it can be a very powerful tool in optimising the component further to improve upon the results. If a company can guarantee their product will withstand a higher loading or last 10 years longer than their competitor, then they will be the first choice to any sensible customer, so long as the components are competitively priced.

INTERESTING CASE
STUDY & DISCUSSION
ABOUT COMARING TEST
& FEA.

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