Full Paper

Introduction

Subjects concerned with the teaching of basic statics and mechanics at tertiary level institutions have seen a progressive decrease, and in some cases, the total elimination of 'hands on' opportunities for students to perform experimental work in support of material presented in the lectures and in tutorials.

The principal reasons offered for this trend is a blend of one or more of the following inter- related circumstances:

1. Increasingly large class sizes making it difficult to timetable and resource such activities
2. Competition for dedicated shared laboratory space from escalating needs to perform more research at institutions
3. The commercially available teaching apparatus from the major vendors remains expensive
4. The availability/development of cheaper technology that 'simulates' experimentation through videos and animation

The author has over 40 years' experience in the teaching of such material and has witnessed this progressive trend to the point where he has observed its effects on large student classes as being nothing short of detrimental to their effective learning and better understanding of this material.

The pendulum has swung too far away from 'hands-on' opportunities for performing experimentation by students in support of inferior learning mechanisms. Technology itself must come to the rescue to swing back the pendulum to create 'hands on' resource- affordable experimentation opportunities for students thus improving their engagement and interest in this style of material and bringing back the **fun** in their learning experience.

"Putting your money where your mouth is"

With this premise in mind, (resurrect fun 'hands-on' experimentation opportunities for Engineering students), the author has developed a series of teaching products in Basic Mechanics that goes a long way towards mitigating the shortcomings of the status quo in this area, bringing **stimulation** back to these topic areas in lieu of inferior **simulation**.

He has gone to some effort to introduce innovations in his TechnoLab™ series of products that make visibly clear the objective of the particular experimentally-based exercise in a "seeing is believing" context. Whilst it is possible to satisfy the requirements of the learning exercises for students with what can plainly and directly be observed by them in performing these experiments, further enhancement in this learning experience is afforded them through the use of **photogrammetry** and/or direct visual comparison with predicted/simulated results for the exercises concerned, (Haritos, 2014).

The approach adopted by the author is one where deflections/deformations in the elements subjected to test loading (eg the deflected shape of a rectangular cantilever beam to a point load part-way along its span) are clearly visible as the test element is quite flexible to low level loading.

This philosophy of clearly visible deformations to applied actions is a common thread throughout the development of a wide range of experiments that students can perform on a versatile test frame trademarked as the Pixi Frame™. It mirrors what is often done in class with visual aids where deformations are exaggerated in the presentation material to be better able to clarify and visualise the concepts introduced, eg strain fields in flexure where "plain sections remain plain"; nodal deformation in trusses to illustrate steps in the direct stiffness method, change in sign of curvature (zero bending moment), among others).

Significant improvement to visual measurement/recording of the deformation response of elements under test is afforded through the use of **photogrammetry** in this identification.

The principal multi-objective goal in developing the TechnoLab teaching platform is to enhance the learning experience of large cohorts of students in Mechanics through the innovative design of "hands-on" engaging experimentation that:

(i) is portable, easy to assemble

(ii) does not require special facilities or instrumentation

(iii) is versatile and easily expandable

(iv) reduces/eliminates opportunities for plagiarism in experiment reports

(v) offers a large number of experiment options, fully supported by the developer with material including: experiment description sheets; pro-forma reporting sheets; support Excel spreadsheets and software that is experiment dependent; tutor support material

(vi) offers distance learning opportunities

(vii) is affordable in the current financial climate of tertiary institutions throughout the world

Description of the TechnoLab bundle concept in brief

The Basic TechnoLab™ bundle is aimed at a group of 24 to 30 students in a Tutorial environment – no need for Laboratory space per se. A typical bundle consists of 12-15 pairs of Pixi Frames™ with their accompanying Window Frame. An additional pair is provided for the Tutor/Teaching Assistant which can be used to provide a brief demonstration of the experiment being addressed for that particular scheduled time-slot in the Subject program at the beginning of the session. This pair can be released to the classroom for student use after the initial demonstration so an additional pair of students can be catered for. (A near A2 size Midi Frame and a near A1 size Maxi Frame can be substituted for the Tutor Frame should this be seen as desirable to the classroom setup/environment of the particular class).

Two students, one in front and the other behind the teaching frame where the transparent Window Frame is positioned, would work in pairs to perform the experiment, (Figure 1). The window frame can have a removable transparency with a graphical graticule mounted on it onto which deformed shapes/new positioning of the experiment elements can be manually recorded by students for subsequent investigation. Alternatively, a to-scale transparency of the predicted theoretical results can be depicted for a direct "eye-ball" comparison with the experiment. The screen of a suitable laptop/notebook computer or a 2nd stand-alone screen can replace the image on the transparency of the predicted results (Figure 2).

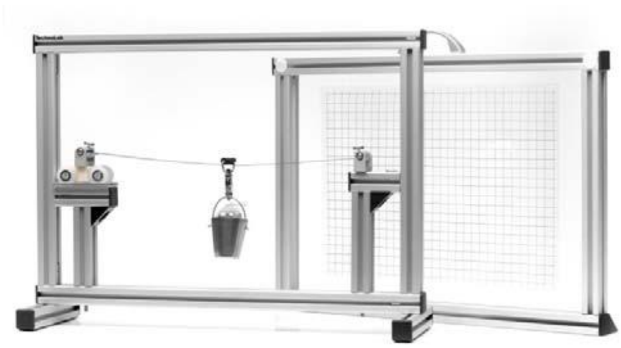

Figure 1: Pixi Frame with Window Frame with Simply Supported Beam Expt.

Figure 2: Pixi Frame with Notebook Prediction Cantilever Expt.

The strategy adopted in the design of the TechnoLab experiments mimics to a large extent that adopted in lectures. For the example case of investigating for the reactions in a simply supported beam, lecture slides typically exaggerate the deflected shape of the beam and suggest that if we had load scales at the supports, readings would reflect these reactions.

Consequently, flexural reactions in the TechnoLab series of experiments, (as for example in the simply supported beam experiment depicted in Figure 1), are measured using very accurate digital scales (1000g or 2000g range, both with +/-0.1g resolution).

Figure 3 depicts a simply supported beam using a 1.5mm diameter Carbon Fibre (CF) circular rod as the beam. The loading applied in the experiment uses stainless steel ball bearing balls in a load bucket placed just to the left of centre span, (Figure 4).

The deflected shape is very obvious as is the unimpeded rotations at both ends from the low friction ball bearing swivels. A slight inward movement of the roller/swivel at the right hand support is also observed on application/removal/re-application of the load.

Figure 5 depicts measurement of the applied load using the digital scales. Figures 6 and 7 depict measurement of the Left Hand Side (LHS) reaction by placing the scales under the support rod for the ‘no load’ and ‘applied load’ cases, respectively.

Figure 8 depicts the digital scales under the Right Hand Side (RHS) reaction support rod with the Tare function engaged to “zero-out” the RHS reaction for the no load condition. Figure 9 shows the measurement after the near central load has been applied – now absolute.

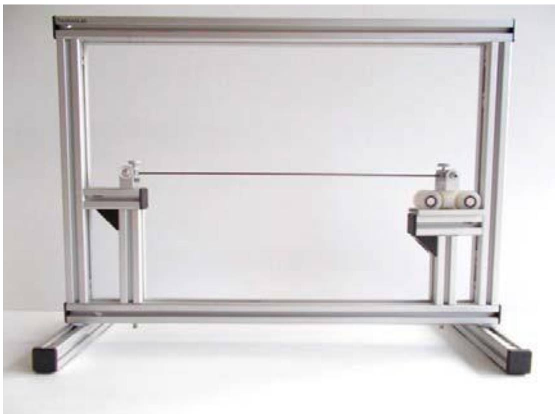

Figure 3: Simply supported CF beam with near (unloaded)

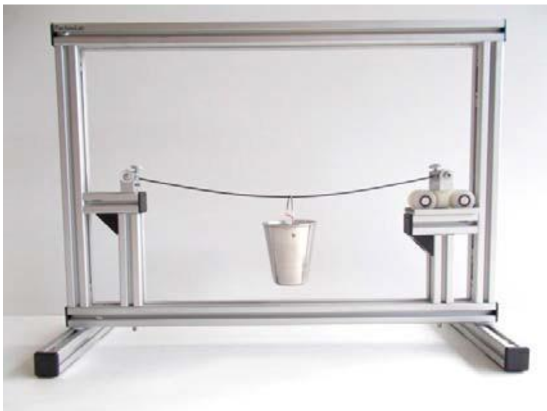

Figure 4: Simply supported CF beam central point load

 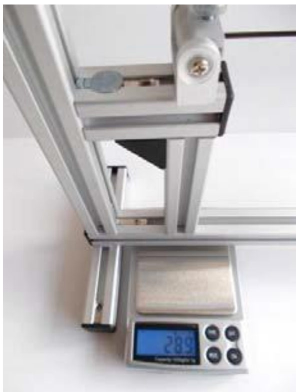 

Figure 5: Applied Load   Figure 6: LHS reaction   Figure 7 LHS reaction for
applied load measurement for 'no load' case case

 

Figure 8: Tare function "zeros-out"   Figure 9: RHS reaction measurement
to the 'no load' reading for RHS reaction   applied load is now
absolute

It transpires that the LHS reaction is determined to be 86.0 – 28.9 = 57.1g (or 0.560 N) and the RHS reaction 52.8g (or 0.518 N). The reactions total to 109.9g (or 1.078 N) which compares favourably (less than 1% error) with the applied load of 110.7g (or 1.086 N).

TechnoLab experiment kits – packaging

The TechnoLab bundle of experiment hardware for each Pixi Frame™/Window Frame fits into a robust Aluminium case of approx. A3 proportions in plan and 140mm deep, so is manageable to store and be retrieved for easy assembly of the relevant experiment kit for the class concerned, (Figure 10). This packaging form is robust enough to be borrowed and taken off campus by campus-based students who may have missed performing scheduled experiments because of illness or other extenuating circumstances. This form also suits sending to pairs of distance-learning students living in close proximity to each other.

An alternate packaging arrangement is one that uses Polypropylene satchels again of near A3 proportions in plan but only 40mm deep, (see Figure 11). These satchels can be easily stored in custom-built deep draw cabinets similar to filing cabinets in terms of design concept and proportions. They are suitable for housing a single or part set of bundled experiments and for short term borrowing by students, if needed.

Figure 10: Aluminium Case with Layered Contents of Frames and Experiment Kits

Figure 11 TechnoLab Polypropylene Satchels with Experiment kits Left: Three-bar Truss and Right: Equilibrium of Planar Forces

TechnoLab experiment kits – developed, being prototyped and being planned

The list of experiments being considered for the Technolab Experiment bundles, and at various stages of development, is reasonably comprehensive, and includes:

(i) The load/deflection characteristics of close-coiled helical springs (a) individual, two springs (b) in parallel and (c) in series. (Figure 12 is relevant).

(ii) Equilibrium of in-plane forces acting (a) at a single point (see Figure 13) and (b) on a 2-dimensional body

(iii) Strain field in a 2-dimensional linear elastic body subjected to direct stresses

(iv) Longitudinal strain distribution in a simply supported beam

(v) Reactions and deflections of simple beams/cantilevers (point and distributed loads)

(vi) Shear force and bending moment in a simply supported beam (a direct and two indirect approaches)

Figure 12: Two springs in parallel and in series, respectively

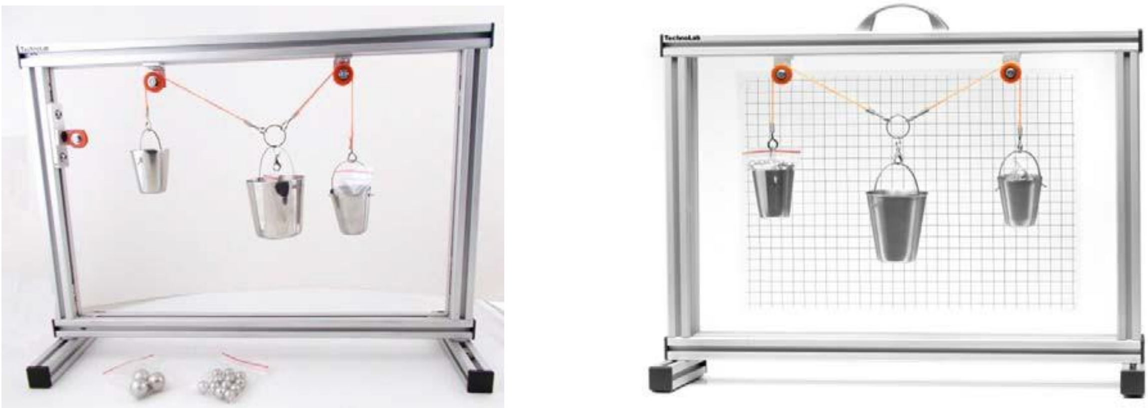

Figure 13: Equilibrium of co-planar forces (300, 500, 400 g case and all 300g, respectively)

(vii) Buckling of columns: Pinned-Pinned; Pinned-Fixed; Fixed-Fixed; Pinned–Fixed Roller; Fixed-Fixed Roller, see Figures 14 and 15. Figure 15 depicts the last two end support condition combinations which correspond to sway buckling.

(viii) Member forces in statically determinate and indeterminate truss systems

(ix) Statically indeterminate systems: (a) two span beam, (b) Propped cantilever, (c) Truss with a single redundant reaction and (d) Single bay Portal frame

(x) Various structural dynamics experiments that include: vibration response and modal characteristics of a cantilever, a simply supported beam and single and two storey sway frames; response of simple frames to “ground motion” suing a linear actuator based earthquake simulator currently under development, etc.

Concluding remarks

The TechnoLab philosophy of producing a teaching platform that: is versatile; expandable; can cover a broad range of Mechanics topics; attractive and engagings; affordable to tertiary institutions; resource averse in terms of technical support required and the physical space needed to run and house the equipment, has all the hallmarks of providing a "turnaround" in the often reported negative student experience in Mechanics style subjects at tertiary level institutions that these students attribute to lack of "hands on" experiment opportunities.

Figure 14: Column Buckling: Fixed-Pinned; Roller; Pinned-Pinned; Fixed-Fixed

Figure 15: Column Buckling: Fixed-Fixed Fixed-Pinned Roller (Sway cases)

Developments to include experiments in Dynamics using the Pixi-Frame™ of the TechnoLab teaching platform, and a controlled linear actuator shaker system, are currently underway.

The philosophy of using images, in this case video frames, is being maintained for the metrological aspects associated with performing these experiments.

Too good to be true ? I guess "you'll believe when you see it".

References

Haritos, N. (2014). *Seeing is believing*. Paper presented at the 23rd Australasian Conference on the Mechanics of Structures and Materials, Byron Bay, NSW.

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