Engineering 2019 v1.1

IA1 high-level annotated sample response

April 2018

Project — folio (25%)

This sample has been compiled by the QCAA to assist and support teachers to match evidence in student responses to the characteristics described in the assessment objectives.

Assessment objectives

This assessment instrument is used to determine student achievement in the following objectives:

1. recognise and describe the structural problem, engineering technology knowledge, and mechanics and materials science concepts and principles in relation to structures
2. symbolise and explain ideas and a solution in relation to structures
3. analyse the structural problem and information in relation to structures
4. determine solution success criteria for the structural problem
5. synthesise information and ideas to predict a possible structural solution
6. generate a structural prototype solution to provide data to assess the accuracy of predictions
7. evaluate and refine ideas and a solution to make justified recommendations
8. make decisions about and use mode-appropriate features, language and conventions to communicate development of the prototype solution.

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171176

Instrument-specific marking guide (ISMG)

Criterion: Retrieving and comprehending

Assessment objectives

1. recognise and describe the structural problem, engineering technology knowledge, and mechanics and materials science concepts and principles in relation to structures
2. symbolise and explain ideas and a solution in relation to structures

The student work has the following characteristics:	Marks
• accurate and discriminating recognition and discerning description of the structural problem, engineering technology knowledge, and mechanics and materials science concepts and principles in relation to structures • adept symbolisation and discerning explanation of ideas and a solution in relation to structures with sketches, drawings, diagrams, graphs, tables and/or schemas.	4–5
• accurate recognition and appropriate description of the structural problem, engineering technology knowledge, and some mechanics and materials science concepts and principles in relation to structures • competent symbolisation and appropriate explanation of some ideas and a solution in relation to structures with sketches, drawings, diagrams, graphs, tables and/or schemas.	2–3
• variable recognition and superficial description of aspects of the structural problem, concepts or principles in relation to structures • variable symbolisation or superficial explanation of aspects of ideas or a solution in relation to structures.	1
• does not satisfy any of the descriptors above.	0

Criterion: Analysing

Assessment objectives

3. analyse the structural problem and information in relation to structures
4. determine solution success criteria for the structural problem

The student work has the following characteristics:	Marks
• insightful analysis of the structural problem, and relevant engineering mechanics, materials science, technology and research information in relation to structures, to identify the relevant elements, components and features, and their relationship to the structure of the problem • astute determination of essential solution success criteria for the structural problem.	6–7
• considered analysis of the structural problem, and relevant engineering mechanics, materials science, technology and research information in relation to structures, to identify the relevant elements, components and features, and their relationship to the structure of the problem • logical determination of effective solution success criteria for the structural problem.	4–5
• appropriate analysis of the structural problem, and engineering mechanics, materials science, technology and research information in relation to structures, to identify some of the elements, components or features of the problem • reasonable determination of some solution success criteria for the structural problem.	2–3
• statements about the structural problem, or information in relation to structures • vague determination of some solution success criteria for the structural problem.	1
• does not satisfy any of the descriptors above.	0

Criterion: Synthesising and evaluating

Assessment objectives

5. synthesise information and ideas to predict a possible structural solution
6. generate a structural prototype solution to provide data to assess the accuracy of predictions
7. evaluate and refine ideas and a solution to make justified recommendations

The student work has the following characteristics:	Marks
• coherent and logical synthesis of relevant engineering mechanics, materials science, technology and research information, and ideas to predict a possible structural solution • purposeful generation of a structural prototype solution to provide valid performance data to critically assess the accuracy of predictions • critical evaluation and discerning refinement of ideas and a solution using success criteria to make astute recommendations justified by data and research evidence.	8–9
• logical synthesis of relevant engineering mechanics, materials science, technology and research information, and ideas to predict a possible structural solution • effective generation of a structural prototype solution to provide valid performance data to effectively assess the accuracy of predictions • reasoned evaluation and effective refinement of ideas and a solution using success criteria to make considered recommendations justified by data and research evidence.	6–7
• simple synthesis of engineering mechanics, materials science, technology and research information, and ideas to predict a possible structural solution • adequate generation of a structural prototype solution to provide relevant performance data to assess the accuracy of predictions • feasible evaluation and adequate refinement of ideas and a solution using some success criteria to make fundamental recommendations justified by data and research evidence.	4–5
• rudimentary synthesis of partial engineering mechanics, materials science, technology or research information, or ideas to predict a structural solution • partial generation of a structural prototype solution to provide elements of performance data to partially assess the accuracy of predictions • superficial evaluation of ideas or a solution using some success criteria to make elementary recommendations.	2–3
• unclear combinations of information or ideas • generation of elements of a structural prototype solution • identification of a change about an idea or the solution.	1
• does not satisfy any of the descriptors above.	0

Criterion: Communicating

Assessment objective

8. make decisions about and use mode-appropriate features, language and conventions to communicate development of the prototype solution

The student work has the following characteristics:	Marks
• discerning decision-making about, and fluent use of, – written and visual features to communicate about a solution – language for a technical audience – grammatically accurate language structures – folio and referencing conventions.	3–4
• variable decision-making about, and inconsistent use of, – written and visual features – suitable language – grammar and language structures – folio or referencing conventions.	1–2
• does not satisfy any of the descriptors above.	0

Task

Context
A civil construction company requires an electronic variable message sign and sign support structure to upgrade a section of busy arterial roadway. Once constructed and commissioned, the electronic sign will be operated by a traffic management centre to provide motorists with travel information about upcoming events, hazards and traffic delays. The concept design requires a cantilever truss-type gantry support structure to be installed to maximise motorist visibility on the upgrade of the straight roadway section. Details relevant to the development of the sign gantry are: • the foundation of the cantilever gantry is to be positioned 3 m from the left roadway kerb with a safety barrier installed to reduce the risk of high speed collision with the structure • the geographic location receives a very high yearly rainfall, has high humidity during the summer months and experiences quite low temperatures in winter, i.e. minimums of 5–10°C • the structure should be developed considering the Wind Region B ultimate design wind speed of 51.9 m/s or 186.84 km/h experienced at the location • the sign must be positioned at least 6.5 m above the roadway to allow clearance for oversize vehicles and span 6 m to provide road kerb clearance and an over-lane sign location • the fixed electronic sign with a mass of 200 kg will cover an area 6 m wide x 1.5 m high on the oncoming traffic side of the gantry structure • the cantilever sign gantry must efficiently withstand the weight force of the electronic sign and a 1.5 factor of safety loading as judged using the beam performance index • the geological engineers have not yet received the results of the borehole logs and geotechnical soil testing for the sign's location. Therefore, the type of footings needed for the new structure have not been supplied with the concept design.
Task
Your task is to use the problem-solving process in Engineering to: • develop a truss-style cantilever sign gantry that meets the requirements of the concept design provided to the civil construction company and those of the geographic location • document the problem-solving process used to predict the solution in a folio • provide the construction company's project manager with a summary report for their consideration. • The folio will include the use of a prototype sign gantry constructed using balsawood and limited amounts of other materials, as required to withstand the specified weight force of the electronic sign and the factor of safety loading, each scaled to 1:20 for prototype development, and only a consideration of the wind region B wind loading on the structure. (Note: Detailed calculations of the torsional forces resisted by the structure are not required.) Given the geotechnical uncertainty of the foundation, the base of the prototype gantry will be mounted securely to a fixed location to be no greater than 200 mm x 200 mm x 19 mm plywood.

Sample response

Criterion	Marks allocated	Marks awarded
Retrieving and comprehending Assessment objectives 1, 2	5	5
Analysing Assessment objectives 3, 4	7	7
Synthesising and evaluating Assessment objectives 5, 6, 7	9	9
Communicating Assessment objective 8	4	4
Total	25	**25**

The annotations show the match to the instrument-specific marking guide (ISMG) performance-level descriptors.

Part A

Communicating [3–4]

discerning decision-making about, and fluent use of folio and referencing conventions

The response includes the folio convention of a contents page (not included in the page count). Headings display thoughtful and astute choices used to organise and communicate the student's thinking during the problem-solving process in Engineering.

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1

Retrieving and comprehending [4–5]

accurate and discriminating recognition and discerning description of the structural problem, engineering technology knowledge, and mechanics and materials science concepts and principles in relation to structures

The response includes information accurately drawn from the context but not simply restated.

The response shows accurate and discriminating recognition and discerning description through use of what the student knows about the context of the problem including the mechanics fundamentals involved in comprehending the related structural concepts and principles.

Problem exploration

What is known about the problem?

- **Materials** used will need to be:
  - corrosion resistant
  - lightweight yet strong
  - easily maintained
  - capable of fabrication off-site and constructed on-site

Consider **material properties** i.e. mechanical, thermal, physical, chemical, and electrical.
Types of joints – dissimilar materials, conductivity, earthing, expansion and contraction, weathering

Assumed:

- the electronic sign is not required to be fabricated for connection to the prototype cantilever sign gantry for project-manager testing
- the base of the prototype will be fixed to a bench-top or similar to provide a rigid foundation for the structure
- the actual sign will be located roadside in such a way as to reduce the environmental impacts of the structure, including erosion and habitat loss
- balsa is the main material that must be used to construct the prototype (glues, other materials and fixings would be required given the nature of the structure)
- for members in tension other lightweight materials might be used e.g. string or card
- loading on the structure is uniformly distributed (UDL)
- the structure is in equilibrium
- barrier protection negates the need to consider the impact strength of the structure.

Boundaries:

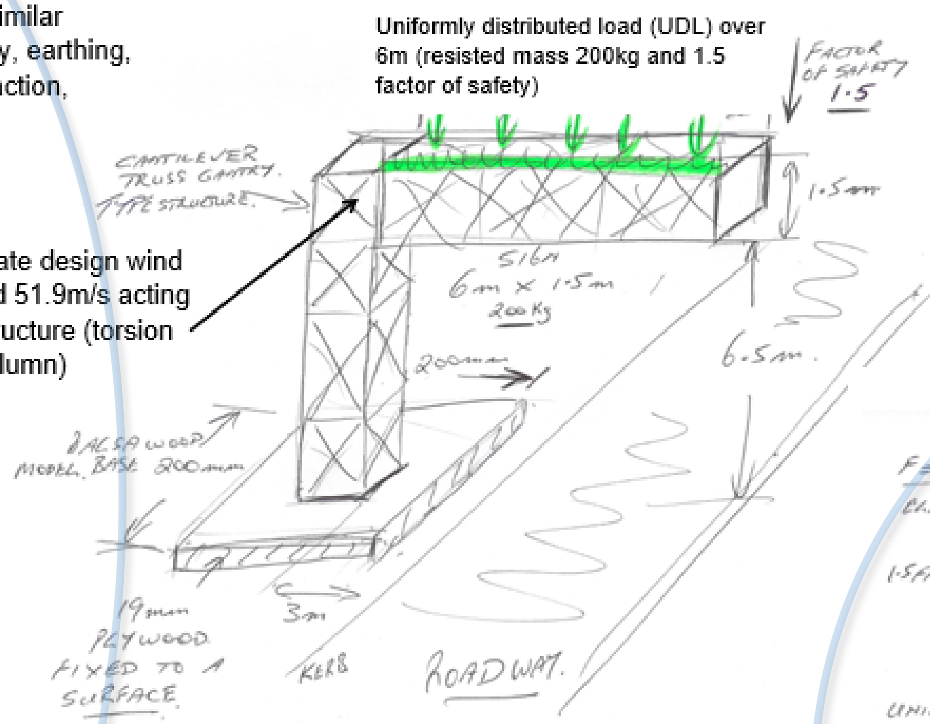
- the prototype must be efficient with the structure built as lightweight as possible to withstand the specified wind, sign and factor of safety loads.

Actual cantilever gantry sign dimensions

(note: plywood base for balsa prototype included)

Uniformly distributed load (UDL) over 6m (resisted mass 200kg and 1.5 factor of safety)

Ultimate design wind speed 51.9m/s acting on structure (torsion on column)



Gantry sign exit 5 - Adam Moss, U.S. Route 67 in Arkansas, 10.02.2017, CCPL

Gantry sign south Phar – formulanone, US83s-US281nsButtonCopyOverheads, 3.08.2012, CCPL

Mechanics fundamentals of the problem

Structure force analysis (What is known)

ACTUAL SIGN STRUCTURE.

F = ma

ELECTRONIC SIGN (F) = 200 Kg × 9.8 m/s² (GRAVITY).
= 1960 N
= 1.96 KN (SCALED 1:20 = 98N).

1.5 FACTOR OF SAFETY = 1.5 × 200 Kg
= 100 Kg
= 100 Kg × 9.8 m/s²
= 980 N
= .98 KN (SCALED 1:20 = 49N).

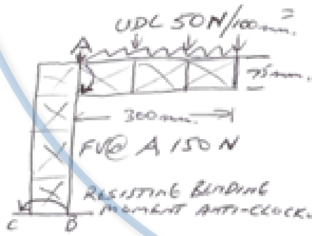
UNIFORMLY DISTRIBUTED LOAD. = 2 KN + 1 KN OVER 6 m
= 3000 N / 6
= 500 N PER m (SCALED 1:20 = 50N PER 100mm)

(Climatec, wind-speed to pressure conversion chart)

WIND PRESSURE ACTING ON THE SIGN 51.9m/s = 2800 Pa
= 2.2 KPa
= 2.2 KN/m².

SIGN AREA = 6m × 1.5m = 9 m²

∴ WIND PRESSURE ACTING ON SIGN = 9m² × 2.2 KN/m²
= 19.8 KN (SCALED 1:20 = 990 N)



CLOCKWISE BENDING MOMENT
ΣM = 0
CONSIDER 150N FV AT A
MA = 150 N × .3 m
= 45 N/m
TRUSS BEAM NEEDS TO RESIST 45 N/m THROUGH THE COLUMN AT BC

Horizontal wind force creates torsional forces in column

2

Analysing [6–7]

insightful analysis of the structural problem, and relevant engineering mechanics, materials science, technology and research information in relation to structures, to identify the relevant elements, components and features, and their relationship to the structure of the problem

The response includes evidence of testing used to analyse the complex relationships between the identified material properties and the statics (simple trusses) principles of the structural problem.

The response analyses information that has a direct bearing on the structural problem.

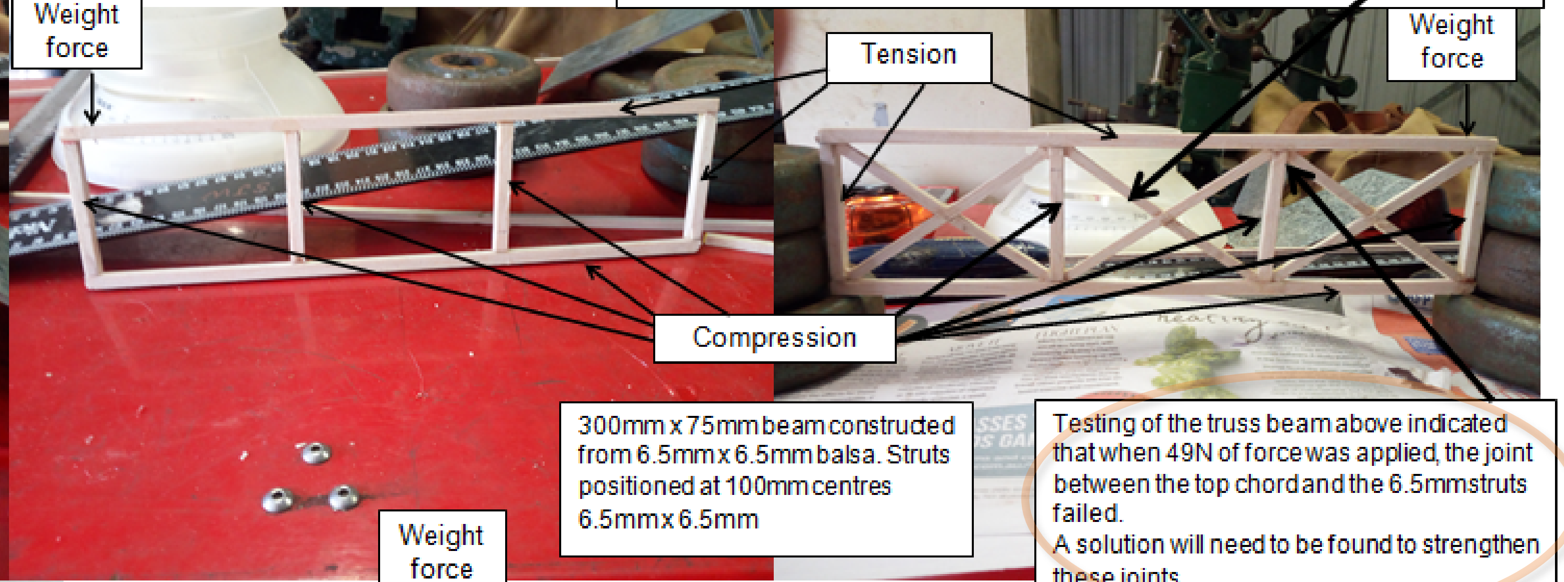
The response identifies relevant elements, components and features, and their relationship to the structure of the problem.

Clarifying unknowns through testing

Testing was conducted to understand aspects of the problem not known. Balsa wood has a very strong strength to weight ratio which is consistent with other hardwood timber species (MakeItFrom.com, Compare Balsa to Hardwood, Mechanical properties in common) i.e. 110KN-m/kg. However, compressive strength is almost 6 times poorer (7.0MPa – 40MPa), ultimate tensile strength is almost 6 times poorer (14MPa – 80MPa), elongation at break is almost one half (1.2 % – 2%), Poison's ratio (lateral strain to axial strain) is almost identical (0.38 – 0.37) and the shear modulus is almost 4 times poorer (0.23GPa – 0.9GPa) (MakeItFrom.com, Compare Balsa to Hardwood, Mechanical properties in common).
Therefore, when constructing with balsa it is important to understand the limitations of the material and where possible find solutions that minimise failure. The sign gantry must support a UDL of 147N and resist a horizontal wind loading of 990N.
The pictures, sketches and annotations below indicate some of the areas analysed.

6.5mm x 6.5mm balsa cross sectional area 0.000042 m^2
6mm deflection across 100mm span – load 24.5 N

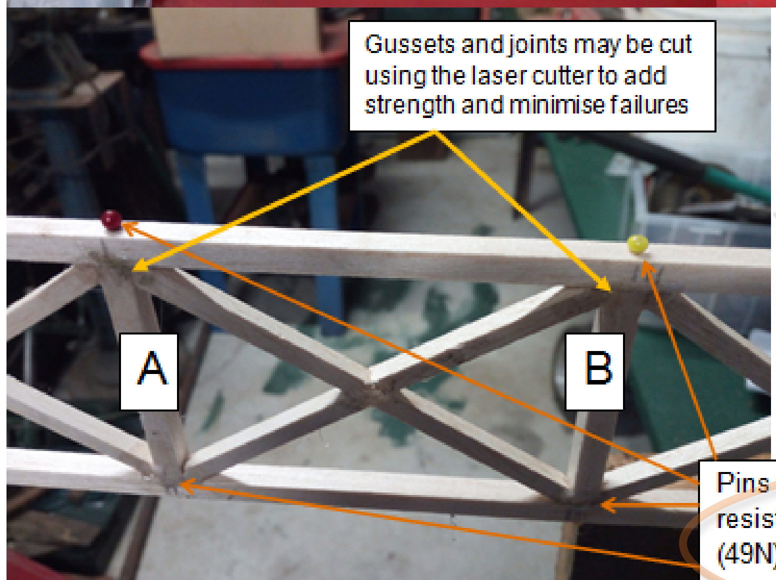
Redundant members included to support struts in compression to minimise distortion of the frame under load. Cross braces 5mm x 5mm



300mm x 75mm beam constructed from 6.5mm x 6.5mm balsa. Struts positioned at 100mm centres 6.5mm x 6.5mm

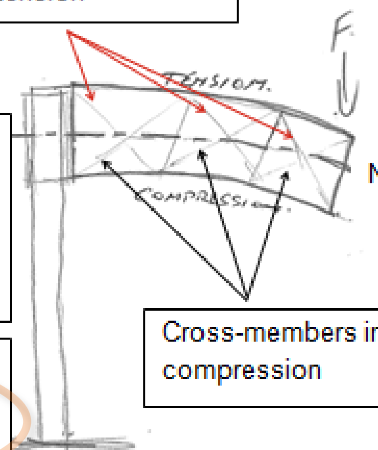
Testing of the truss beam above indicated that when 49N of force was applied, the joint between the top chord and the 6.5mm struts failed.
A solution will need to be found to strengthen these joints

Gussets and joints may be cut using the laser cutter to add strength and minimise failures



Compression is experienced within the horizontal members of the truss beam below the neutral axis.
Tension is experienced within the horizontal members of the truss beam above the neutral axis.
Struts experience compressive forces and ties experience tensile forces.

Cross-members in tension



Cross-members in compression

Pins were added to strengthen the joints. This strengthened the frame structure which resisted deformation about the neutral axis. However, the pins began to bend under the load (49N). This type of joint will need to be very strong. Testing has revealed that glue alone is not strong enough to prevent failure under load.

3

Analysing [6–7]

astute determination of essential solution success criteria for the structural problem

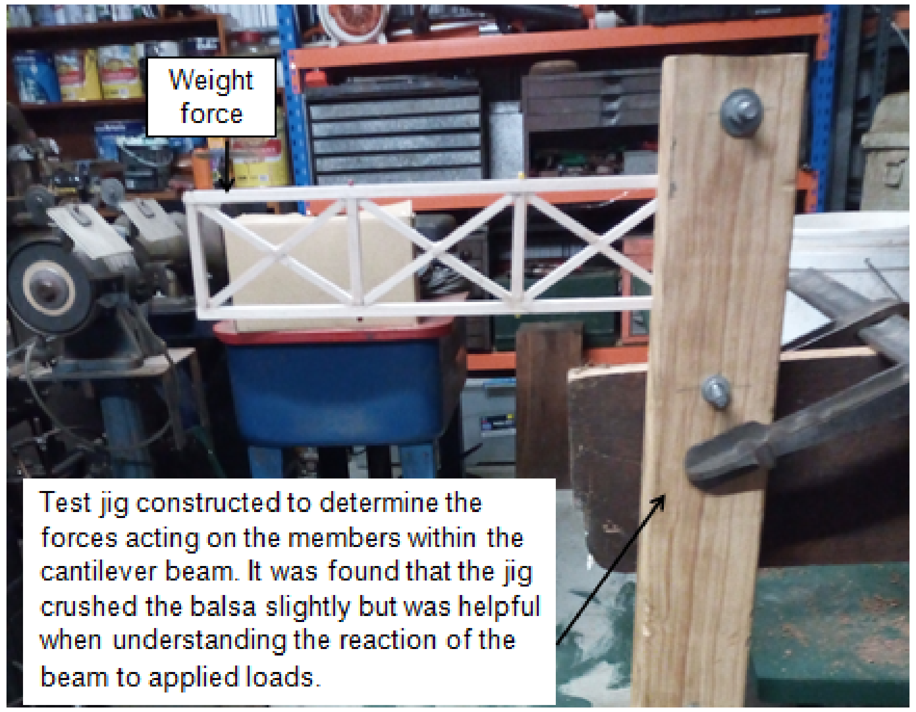
The response displays evidence of an accurate assessment of the problem in order to identify success criteria that are of critical importance to the structural problem solution.

The success criteria acknowledge all aspects of the problem including those relevant to both the actual and the prototype cantilever sign gantry.

The way forward

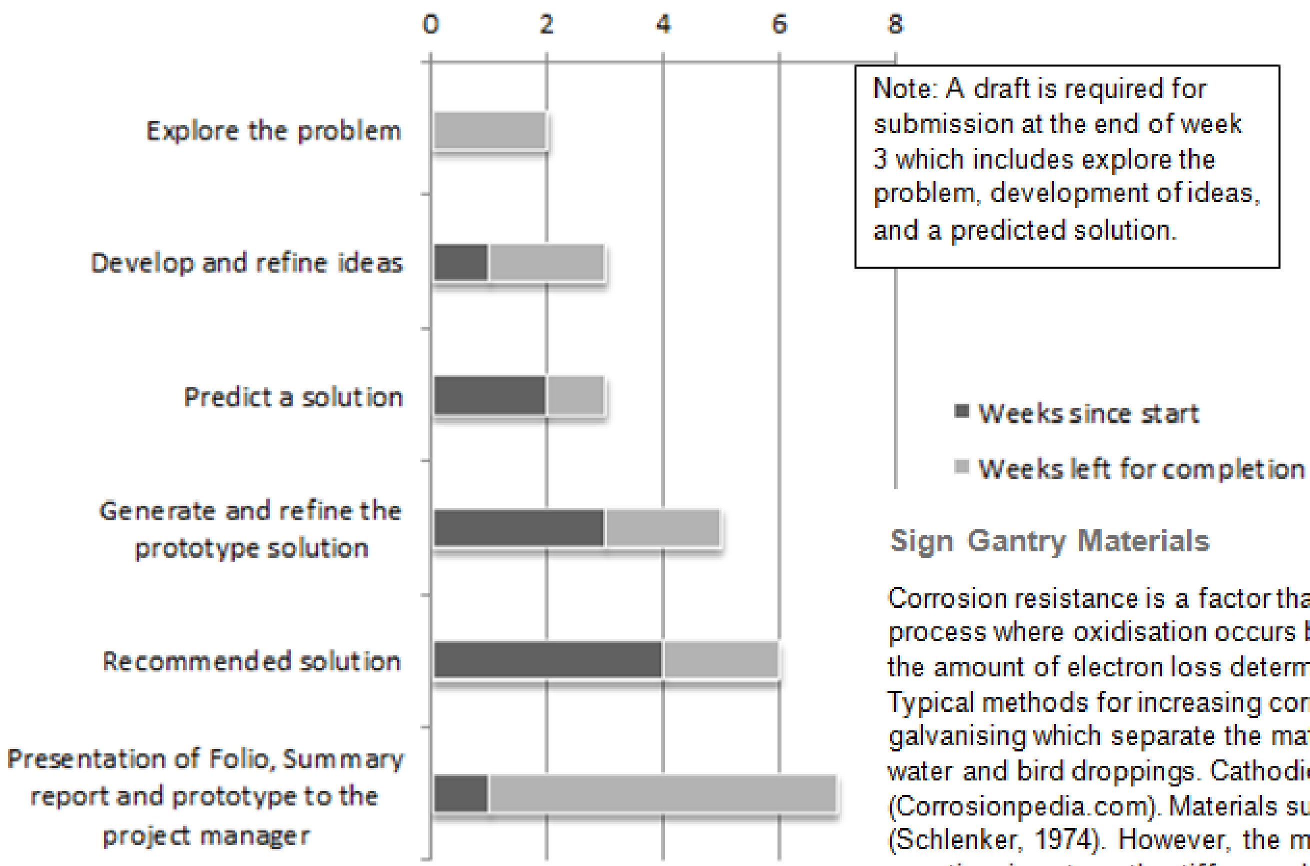
Determining success criteria

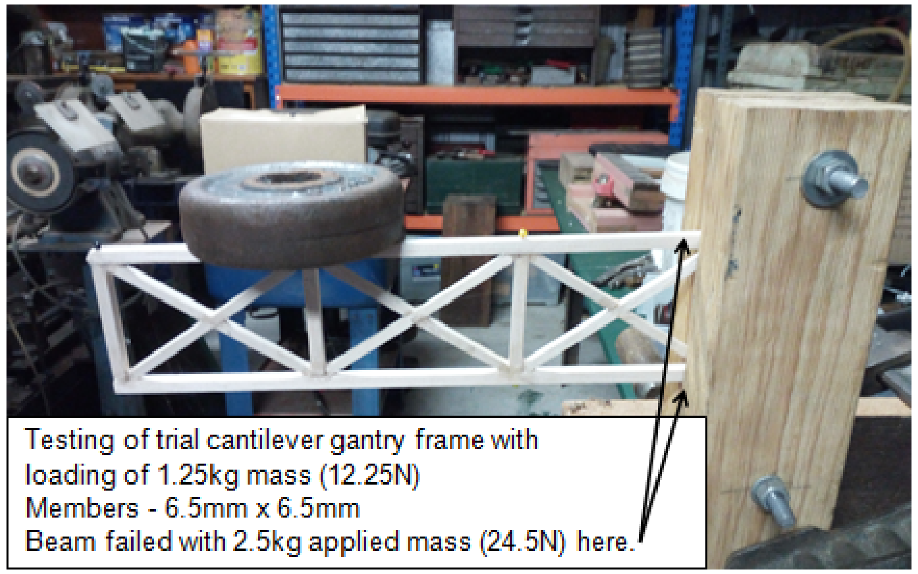
- the cantilever sign gantry structure's efficiency will be determined using the beam performance index: mass supported in grams divided by mass of gantry in grams
- resources for the prototype will be limited to a minimal amount of balsa wood cut into strips as required through idea development and other materials that may be required to support the applied loads (vertical 147N and horizontal 990N) and to keep the structure's mass to a minimum
- the materials recommended for the actual sign gantry must be corrosion resistant, withstand the effects of expansion and contraction and allow for construction on-site after fabrication of significant components off-site and transportation to the site
- the structure should not impact negatively on the environment and be easily maintained over its useful life and be recyclable when no longer required
- work activities to erect the structure should not impact adversely on habitat or create increased risks of erosion during or after construction
- the structure must withstand the applied weight and pressure forces from the variable electronic sign, safety factor and region B ultimate design wind speed



Test jig constructed to determine the forces acting on the members within the cantilever beam. It was found that the jig crushed the balsa slightly but was helpful when understanding the reaction of the beam to applied loads.

Project management (Gantt chart)





Testing of trial cantilever gantry frame with loading of 1.25kg mass (12.25N)
Members - 6.5mm x 6.5mm
Beam failed with 2.5kg applied mass (24.5N) here.

Sign Gantry Materials

Corrosion resistance is a factor that needs to be addressed when selecting materials for the sign gantry. Corrosion is a process where oxidisation occurs between a material and the environment around it causing the material to loose electrons i.e. the amount of electron loss determines the corrosion rate of the material (Corrosionpedia.com).
Typical methods for increasing corrosion resistance are to coat the susceptible materials. Examples include painting and galvanising which separate the material from the corrosive action of the environment, such as the chemicals present in rain water and bird droppings. Cathodic protection is often used for materials that remain in water or underground (Corrosionpedia.com). Materials such as zinc, magnesium, aluminium, brass and copper exhibit resistance to corrosion (Schlenker, 1974). However, the mechanical properties of the material are important for structures that must support loads over time i.e. strength, stiffness, elasticity and fatigue properties (Schlenker, 1974). Observations of roadside sign structures indicates that typically they are constructed from galvanised (zinc) coated steel of various cross sections and sizes.

4

Synthesising and evaluating [8–9]

coherent and logical synthesis of relevant engineering mechanics, materials science, technology and research information, and ideas to predict a possible structural solution

The response provides evidence of an ordered, logical and well-structured synthesis of ideas that incorporate research evidence and the use of mechanics and materials science information to move towards predicting a solution.

Retrieving and comprehending [4–5]

adept symbolisation and discerning explanation of ideas and a solution in relation to structures with sketches, drawings, diagrams, graphs, tables and/or schemas

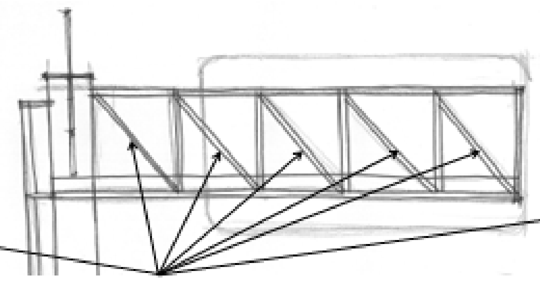
The response provides evidence of a very high level of skill and proficiency when sketching or drawing ideas and solutions.

Pictures, sketches and annotations are used to explain ideas and solutions in a manner that demonstrates intellectual perception and good judgment.

Developing ideas

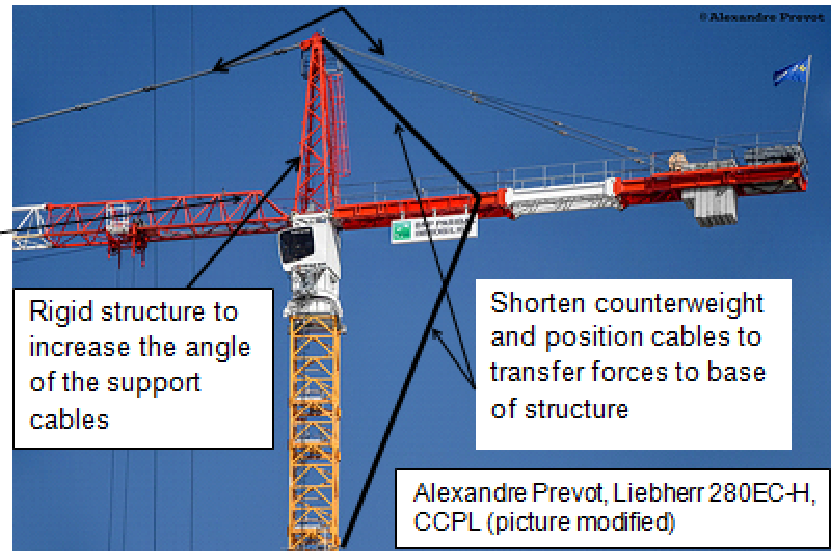
Cantilever sign gantry structure

Ken Lund, Exit 103, Exits 98A-C, Interstate 55 Northbound, Jackson, Mississippi, CCPL (picture modified)



Members here (ties) are in tension, with no corresponding diagonal struts under compression. This would be worth testing to see if the reduction in weight would also reduce strength. The vertical members and bottom chord would be under compression with the top chord under tension

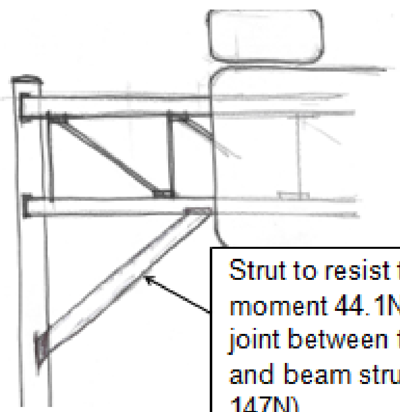
Tower cranes use cables acting on the structure under tensile load to resist applied loads to the structure. This transfers forces to other areas of the structure e.g. counterweights. It would not be efficient to use counterweights, but this engineering principle might be worth considering in the cantilever sign gantry structure



Rigid structure to increase the angle of the support cables

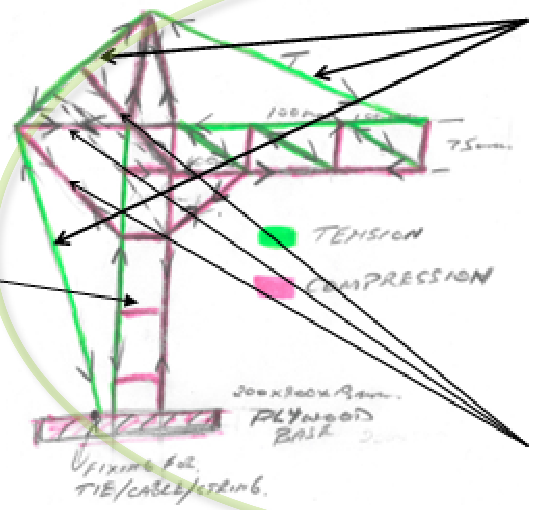
Shorten counterweight and position cables to transfer forces to base of structure

Alexandre Prevot, Liebherr 280EC-H, CCPL (picture modified)

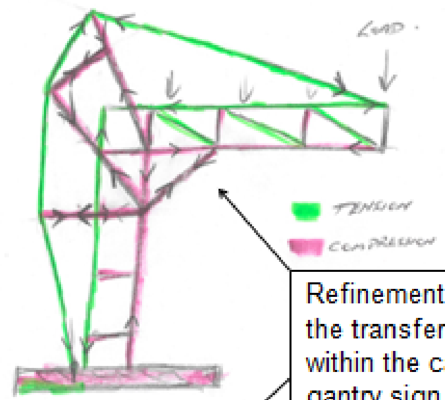


Resisting torsion in the column truss by use of cross-members

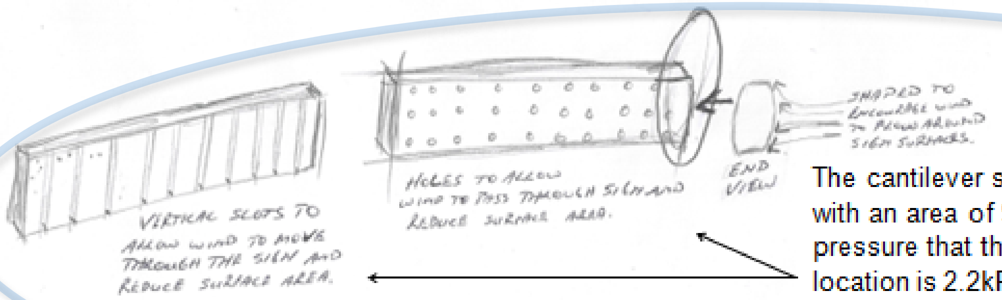
Strut to resist the bending moment 44.1Nm force at the joint between the column and beam structure (load 147N)



The cable idea is an attempt to understand how the compressive forces in the bottom cord of the beam and the inside of the column might be counteracted. The tensile force in the cable is transferred to the structure through the struts as a compressive force which acts in the opposite direction to the reactive forces on the structure due to the applied 147N load. The cable increases the size of the lever arms within the structure.

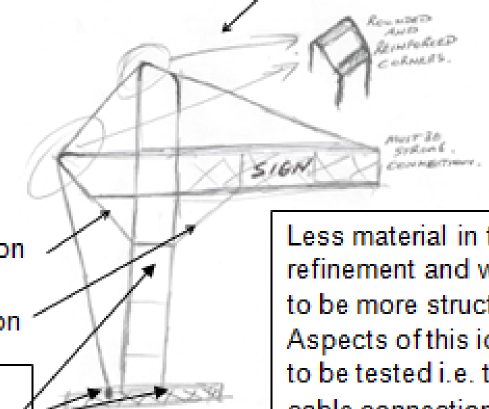


Refinement of ideas for the transfer of forces within the cantilever gantry sign structure



Variable sign wind loading reduction

The cantilever sign gantry must support an electronic sign with an area of 9m² and a mass of 200kg. The wind pressure that this sign must withstand in the region B location is 2.2kPa or 2.2kN/m². A method for reducing the force acting on the sign due to wind is to reduce the sign surface area or alter the flat sign surface to become more aerodynamic.



Tie in tension
Strut in compression

Resisting the BM of 44.1N/M

Less material in this refinement and would seem to be more structurally sound. Aspects of this idea will need to be tested i.e. the joints and cable connections.

5

Synthesising and evaluating [8–9]

critical evaluation and discerning refinement of ideas and a solution using success criteria to make astute recommendations justified by data and research evidence

The response provides a detailed evaluation of the predicted solution using the success criteria and provides a range of recommendations that accurately assess the problem with reference to the success criteria.

The life-cycle analysis evaluates the material properties of steel to recommend its use as the material for the actual sign gantry structure.

Retrieving and comprehending [4–5]

adept symbolisation and discerning explanation of ideas and a solution in relation to structures with sketches, drawings, diagrams, graphs, tables and/or schemas

The response provides evidence of a very high level of skill and proficiency when sketching or drawing ideas and solutions.

Predicting a solution

The prototype sign gantry structure has been developed with an understanding of the limitations of the main construction material of balsa. The sizes have been kept as small as possible i.e. 6.5mm x 6.5mm ties and struts and 12mm x 6.5mm top and bottom truss beam chords and column posts to reduce mass and improve the structures efficiency. Keeping ties and struts the same size improves the manufacturing efficiency of the structure when compared to the small improvement in structural efficiency produced by a minimal reduction in the size of ties.

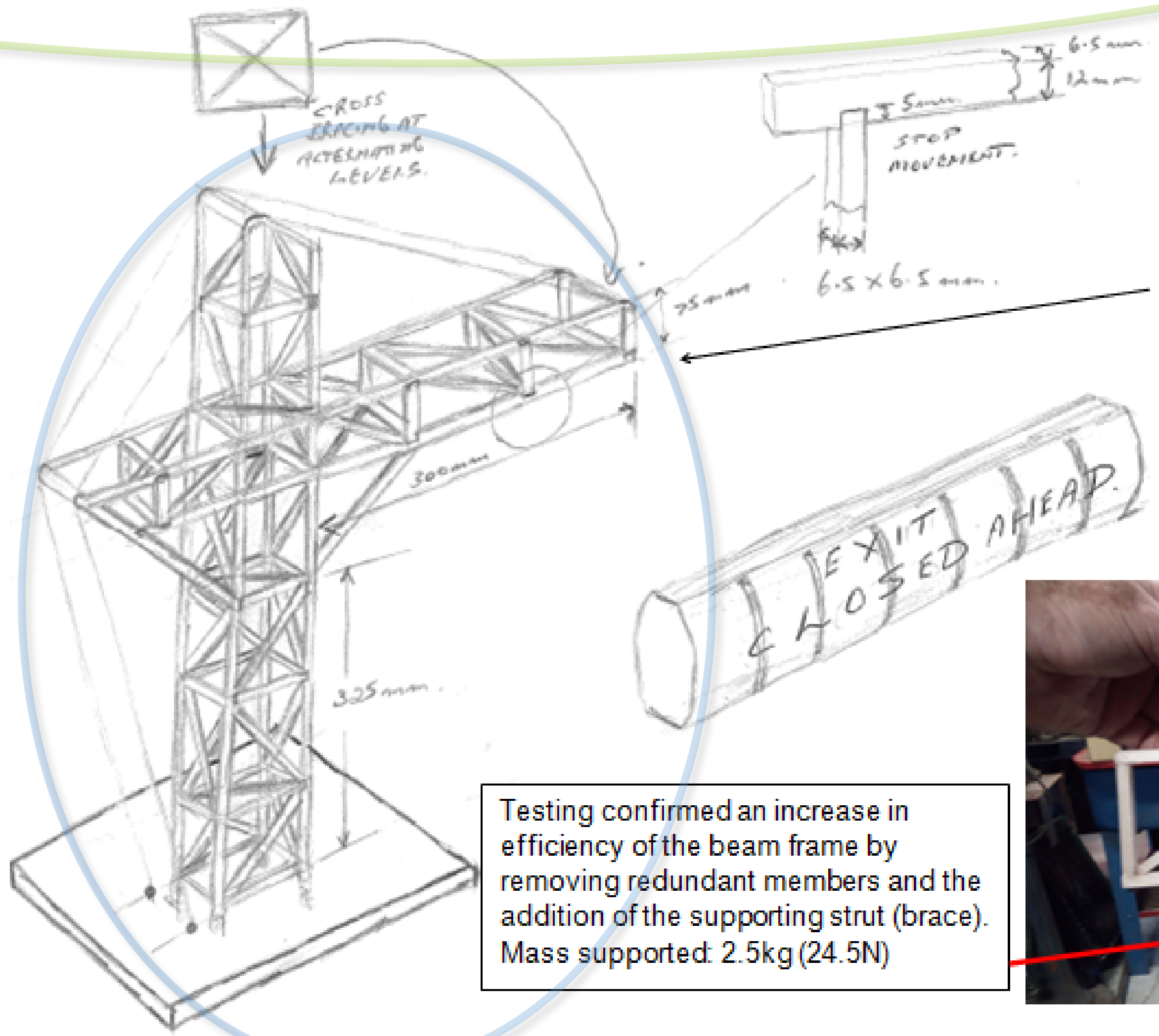
For the actual sign gantry structure the use of the cable acting in tension enables the structure to be constructed of lightweight materials which reduces its carbon footprint. The carbon footprint of this structure is determined from cradle (i.e. design, raw material extraction, materials processing, production and construction) through its useful life and ultimately disposal, including recycling (i.e. to grave) (The Environmental Literacy Council, Life cycle analysis). It is predicted that the actual sign gantry would use much smaller members because of the proposed solution. The structure would be light yet strong, which would allow the beam and column to be constructed off-site and transported easily to location where the two sections would be fixed together. It is predicted that the actual structure would be constructed from mild steel angle and hot dipped galvanised after welding of the two sections (note: that the actual size of the material will be determined once the geological engineers footing report for the location is provided). The sections would be bolted together on site and 10mm diameter high-tensile galvanised steel cables attached and pre-tensioned to 2.94kN of force before fixing the sign to the beam. The wind loading pressure on the structure over the sign area will be reduced by aerodynamically shaping of the sign face and removal of material using slots. This will allow the wind to pass over and through the sign.

Life cycle analysis

The major components of the cantilever sign gantry will be fabricated from mild steel and hot dipped galvanised prior to erection on-site, because:

- steel is manufactured from iron using processes that incorporate recycled content
- energy consumption and carbon emissions during steel manufacture has and continues to reduce significantly
- steel has a high strength to weight ratio and therefore the structure requires less material
- steel is low maintenance when appropriately coated
- steel can be recycled or reused endlessly without any impact on its material properties
- steel has a high economic value at all stages of recycling with highly efficient infrastructure being in place to economically recover and recycle the material
- waste is reduced by fabrication off-site using efficient workplace practices
- structures are produced to specifications under controlled conditions i.e. welding is tested and joints are accurately cut using various CADCAM machinery e.g. laser or high-pressure water jet cutters

(SteelConstruction.info, Sustainability)



Predicted solution

Investigations of like structures (tower cranes and road signs), testing of ideas, balsa material properties, frames and calculations indicates that this form of the structure should support the specified load efficiently without failure. Therefore, this solution will be generated for testing and evaluation using the beam performance index.

Testing confirmed an increase in efficiency of the beam frame by removing redundant members and the addition of the supporting strut (brace). Mass supported: 2.5kg (24.5N)

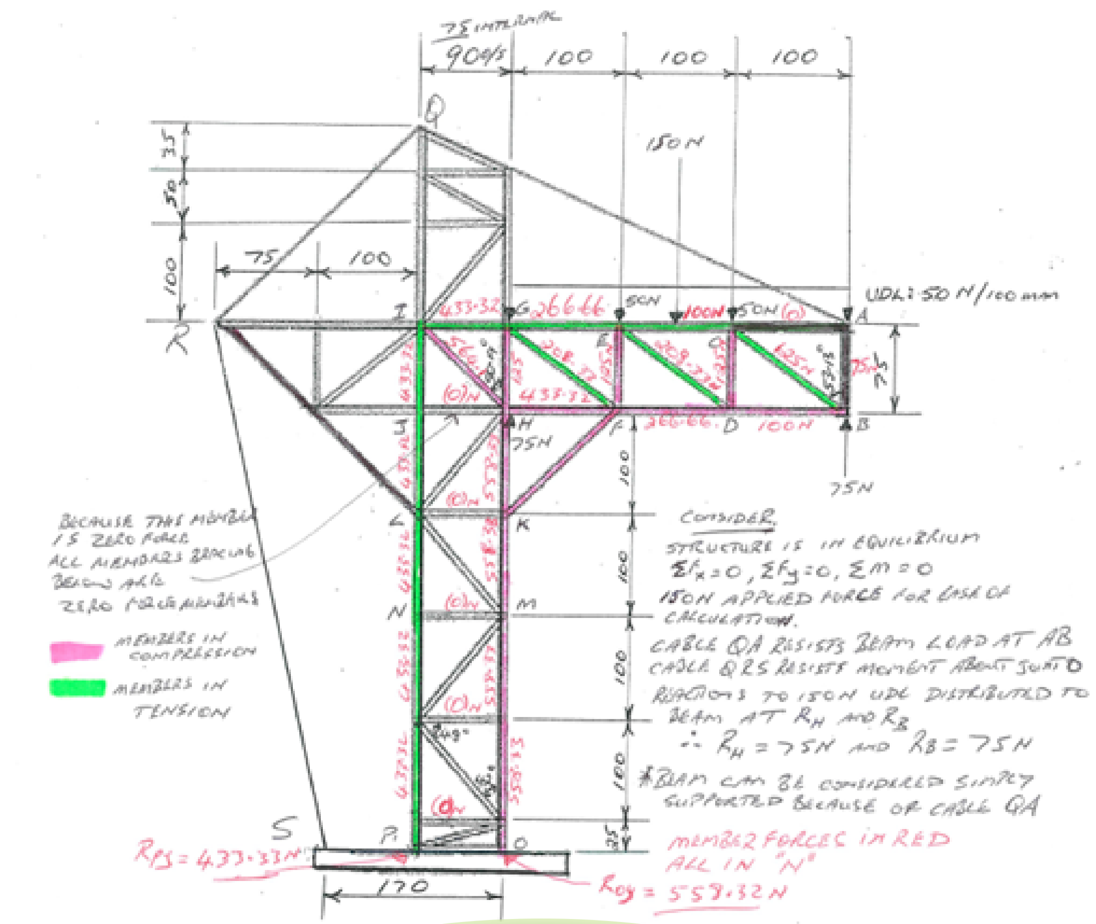
6

Synthesising and evaluating [8–9]

coherent and logical synthesis of relevant engineering mechanics, materials science, technology and research information, and ideas to predict a possible structural solution

The response provides evidence of sound reasoning and an ordered, well-structured synthesis of mechanics, materials science, research and technology information to predict the solution to the sign gantry structural problem.

Structural analysis



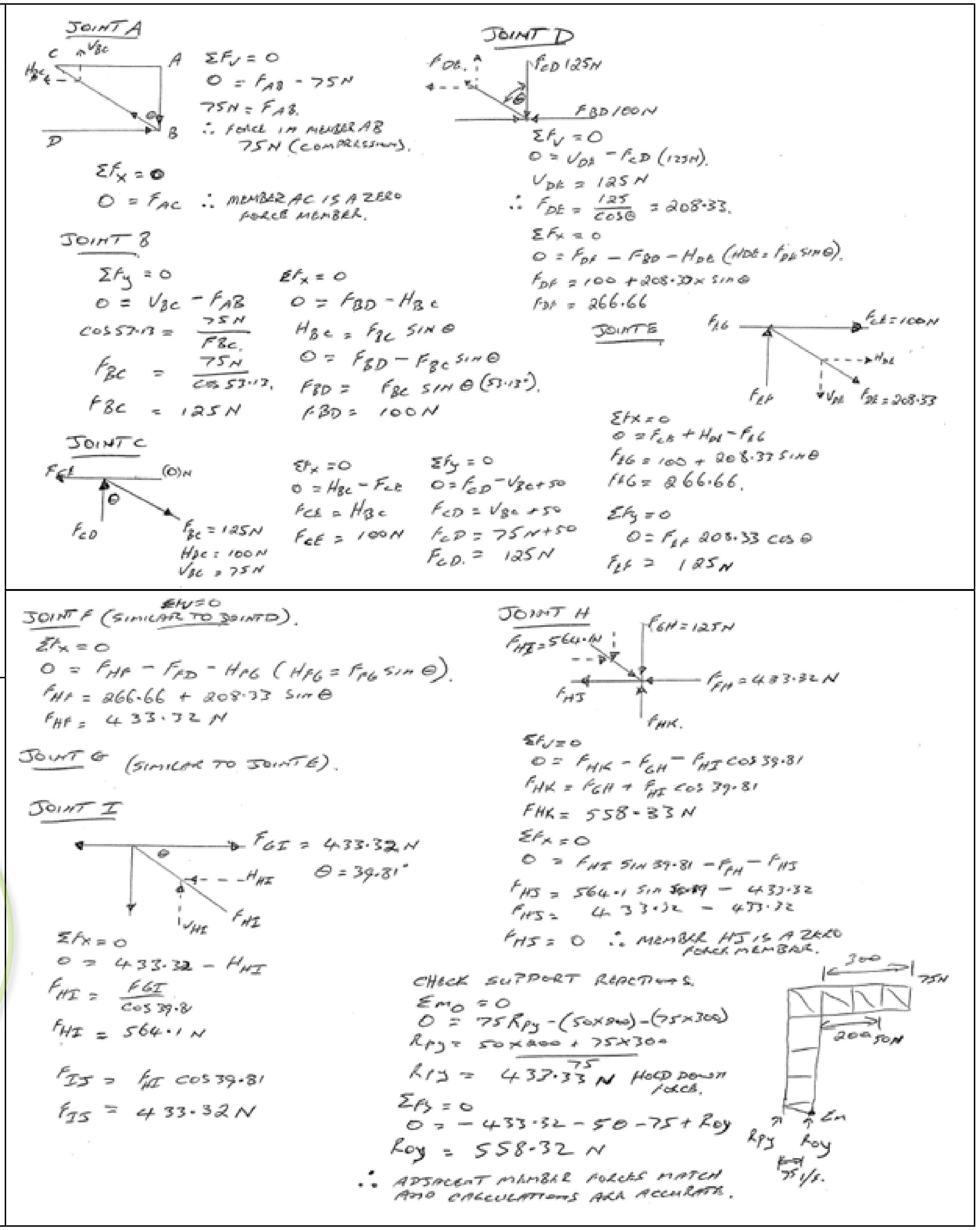
The structural analysis of the predicted solution indicates that the sign gantry structure should transmit the150N weight force applied to the beam truss to the column truss of the structure where the column is reacting at the foundation with an equal but opposite force at P and O. The use of the bracing member FK recognises the large compressive forces present in members HF and FD. Testing of the structure will focus to some extent on how well the structure resists the buckling of column members as a result of the large compressive forces within the column. Zero force column truss bracing members should prevent buckling of members in heavy compression. The material properties of balsa indicate that it has a poor ability to resist both compressive and tensile forces and therefore where required along the truss and column, cardboard gussets will be used to strengthen the glued joints under high force loads to resist shearing.

The cable BAQRS restricts deflection of the beam truss when under load by resisting the uniformly distributed load over members AC and AB. These are determined to be zero force members. The cable also acts to resist the turning moment about O by increasing the lever arm from 75mm internal measurement to 170mm.

Torsional forces (turning moment caused by sign wind pressure) to be resisted by the structure is 341.55Nm (scale1:20) i.e. M = Fd ∴

M = 990N x 0.345m (to centre line of column)

M = 341.55Nm



7

Retrieving and comprehending [4–5]

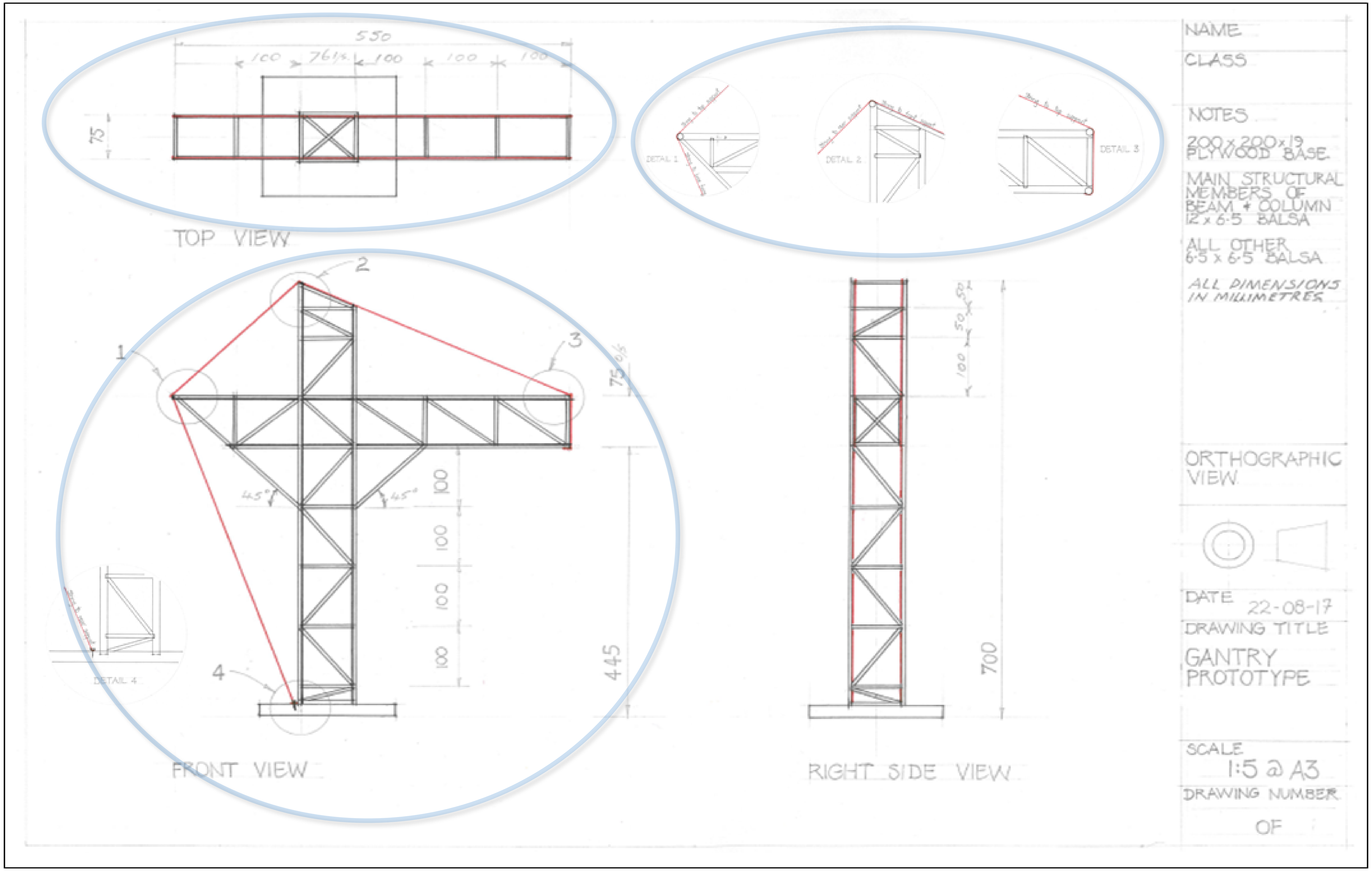
adept symbolisation and discerning explanation of ideas and a solution in relation to structures with sketches, drawings, diagrams, graphs, tables and/or schemas

The response provides evidence of a very high level of skill and proficiency when sketching or drawing ideas and solutions.

The engineering drawing uses appropriate basic drawing standards to fully and clearly provide relevant information to support prototype production.

Generate the predicted prototype solution

Engineering drawing (orthographic)



8

Synthesising and evaluating [8–9]

purposeful generation of a structural prototype solution to provide valid performance data to critically assess the accuracy of predictions

The response provides evidence of the generation of a prototype solution that has the intended and desired result.

The prototype provides legitimate and defensible performance data using the beam performance index and observations to objectively analyse the solution's merits and faults in order to assess the accuracy of the predictions made.

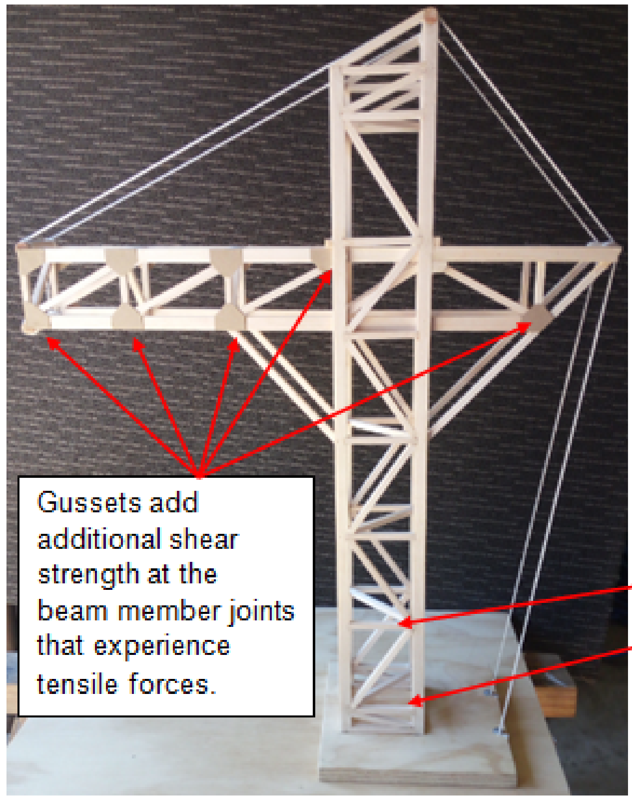
Synthesising and evaluating [8–9]

critical evaluation and discerning refinement of ideas and a solution using success criteria to make astute recommendations justified by data and research evidence

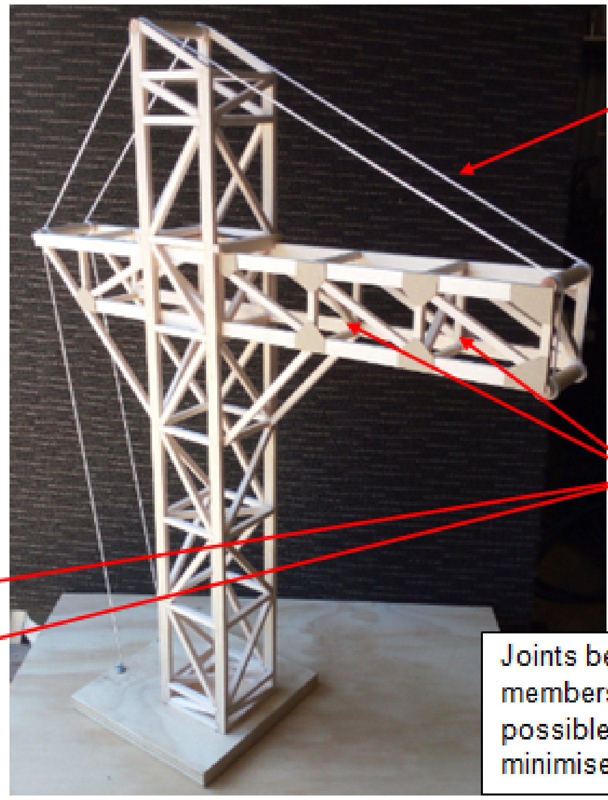
The response provides evidence of refinement based on initial testing of the prototype solution relative to the success criteria.

Prototype cantilever variable sign gantry

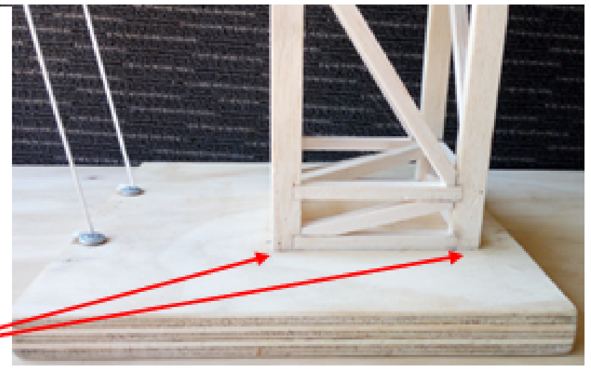
Before testing



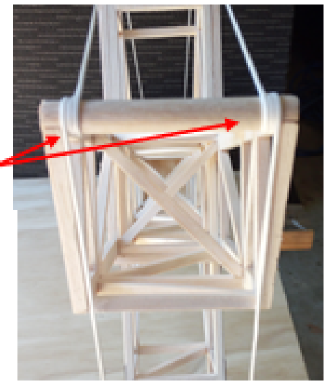
Gussets add additional shear strength at the beam member joints that experience tensile forces.



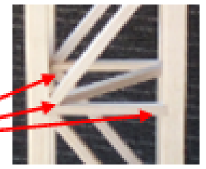
The completed prototype sign gantry has a mass of 98 grams.
The sign gantry structure is mounted 10mm into the base to provide a solid foundation for testing and to resist the bending moment of 45 N/m and torsional forces of 341.55Nm.



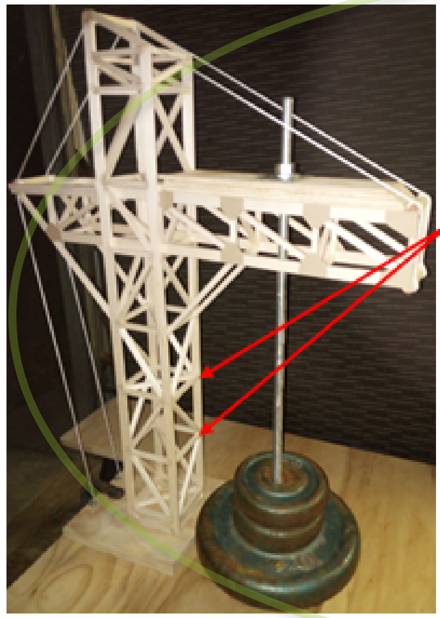
The column and beam are cross-braced alternately at each section to resist torsion forces. String is fixed to the sign gantry and tensioned prior to loading. At each mounting point the string is wrapped and glued to prevent slipping.



Joints between the truss beam and column members were made as accurately as possible to increase glued surface areas to minimise shear failure.

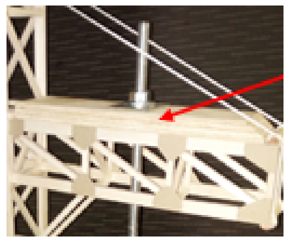


Test results

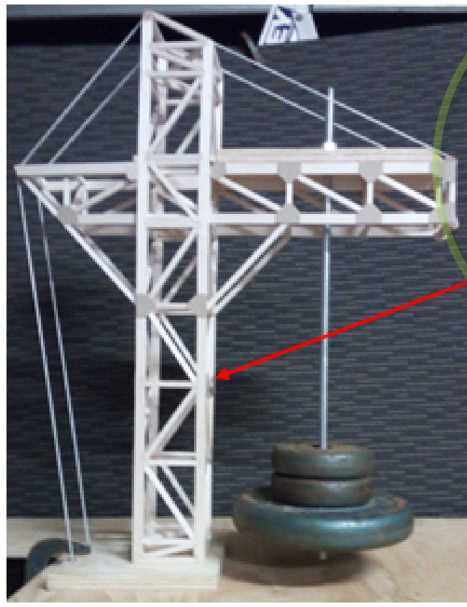


The prototype sign gantry resisted the applied force of 150N (15kg) without failure (note that the test jig added an additional 800 grams mass). However some buckling of the column members was noted during the test. Gussets have been added to prevent shear at the joints where members under compression displayed buckling as indicated.
Efficiency of the structure using the beam performance index = 153.06
The structure exhibited a deflection of 10mm when loaded which indicates that the structural design is appropriate for the purpose of supporting the variable sign at the required location. The internal cross-bracing members resist the torsion created by the applied horizontal wind force. Zero force members prevent the buckling of members in compression.

15kg mass supported from the truss beam by 12mm booker rod, plate, washer and nut.



Test jig top plate uniformly distributes a 150N load across the truss beam.



Gussets added to reduce shear at joints due to compression forces causing buckling of column truss members.

9

Synthesising and evaluating [8–9]

critical evaluation and discerning refinement of ideas and a solution using success criteria to make astute recommendations justified by data and research evidence

The response provides a detailed evaluation of the predicted solution using the success criteria and provides a range of recommendations that accurately assess the problem with reference to the success criteria.

The response provides evidence of intellectual perception in the refinement of the predicted solution to recommend future developments.

Recommendations

Materials and fabrication

It is recommended that the cantilever variable sign gantry be fabricated off-site in two sections, the beam and column. This reduces the cost of transporting the structure to site and the installation costs associated with crane size or safe working load (SWL) (Workcover Queensland, 2017). The column will be bolted to the foundation (developed by others) and the beam bolted to the column after sliding through the column. Four braces will be bolted in position to support the beam to the column frame. Two 10mm high-tensile galvanised cables will be mounted to the frame and foundation, and pre-tensioned to 2.94kN to aid support of the applied loads. The cables will add 7.5kg to the overall weight of the structure; however they will provide greater load carrying efficiency as the minimum breaking force of the cable is 68.6kN (Nobles, 2017), which provides a greater factor of safety than specified. This is recommended given the region B design wind speeds at the location and the position of the sign and framework above the busy arterial roadway. All bolt holes will be drilled prior to galvanising to reduce the risk of corrosion at the bolted assembly points. The use of mild steel angle as the material for fabrication of the gantry beam and column frames allows for welding off-site and hot dipped galvanising prior to installation. The zinc rich galvanised coating provides a low maintenance solution to the environmental conditions of the installation site due to its complete coverage of the base steel material and its cathodic properties which repairs areas that become scratched or slightly damaged during installation or in use (Korvest galvanisers, 2013). Steel was also selected because of its high economic value at all stages of recycling and because structures can be efficiently and accurately produced to specifications under controlled conditions to minimise waste and maximise strength. The aerodynamically shaped and slotted variable sign will be lifted in place and bolted to the frame after erection of the cantilever gantry.

Environmental considerations

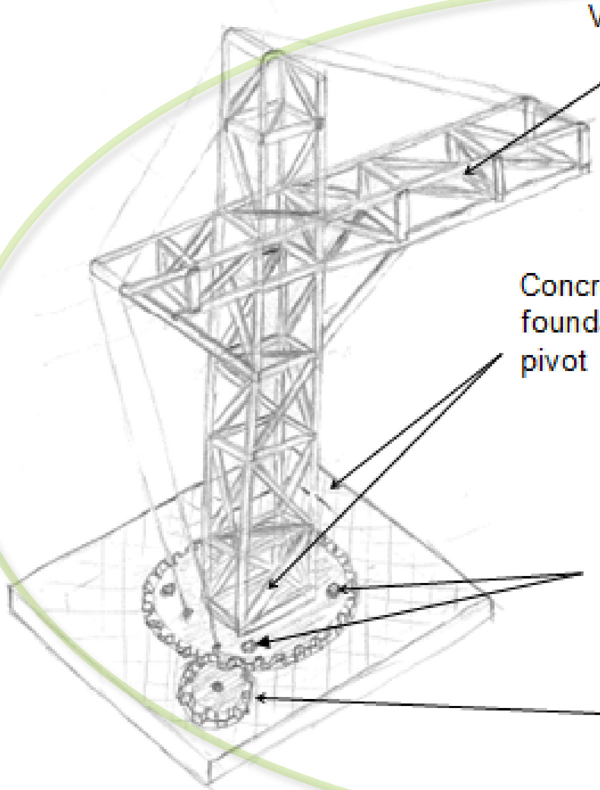
The fabrication and zinc coating of the structure off-site requires less construction time on-site. This minimises the negative impacts of road closures, diversions or reduced speeds on the travelling public. Risks to construction workers are also kept to a minimum by the method of assembly and reduction of exposure to hazards i.e. vehicular traffic, exposure to weather, working at height and overhead lifting of materials by crane.

Less time on-site reduces the impact to native habitat including the soils and vegetation. Disruption to the native animals is also kept to a minimum through the use of the recommended fabrication and installation methods.

Future developments

The cantilever variable sign gantry may be further developed by consideration of the social and environmental impacts of the installation and ongoing maintenance of the gantry framework and electronic variable sign. The structure could be made stronger to support a walk on gantry to allow maintenance of the sign. However, work would be conducted above the traffic, which is dangerous for maintenance workers and the traveling public. The other option would be to delay or divert traffic, which would cause inconvenience and frustration.

An option is to develop the structure so that it can be assembled and erected parallel to the road and pivoted out over the roadway using a mechanical gearing, winch or pulley system and locked into position for use. This would also allow maintenance to be performed on the sign and structure away from the busy arterial roadway. To accommodate this modification to the proposed solution, changes would be required as indicated in the adjacent drawing.



10

Part B

Communicating [3–4]

discerning decision-making about, and fluent use of,

- written and visual features to communicate about a solution
- language for a technical audience
- grammatically accurate language structures

The response includes written and visual features selected for value and relevance to communicate about a solution.

The response includes good judgment concerning the use of grammatically accurate language structures.

Summary report

Cantilever variable sign gantry

Introduction

This document summarises the findings and outcomes of the cantilever variable sign gantry testing and construction completed between August and October 2017.

Background

The project team was commissioned by the construction company project manager to develop, test and construct a prototype cantilever variable sign gantry suitable for a busy arterial roadway. This new sign positioned on the gantry will be operated by the local traffic management centre to inform the travelling public of upcoming events, hazards and traffic delays. The geographic location of the sign gantry receives a very high yearly rainfall, has a high humidity during the summer months and experiences quite low temperatures in winter of 5 to 10 degrees Celsius minimum. The concept design required the development of a structure that will withstand the sometimes significant wind events as experienced in the region B location.

Project objectives

The project objectives were to document the development, testing and construction of a prototype cantilever variable sign gantry within the duration of the project and to ensure that the structure is suitable to meet the specifications as provided in the contract documents and concept design. The success criteria for the project were determined to be that:

- the sign gantry structure is efficient as determined by the beam performance index
- the resources for the prototype gantry will be restricted to balsa wood and a minimal amount of additional materials as determined by the project team to maintain the structures efficiency
- the materials recommended for the actual sign gantry must be appropriate for the environmental conditions of the site location
- the structure should not negatively impact on the environment, be easily maintained and recycled at the end of its useful life
- activities to construct the sign gantry should not impact negatively on habitat, including erosion during and after construction
- the sign gantry must hold the required loads as specified using a truss type structure

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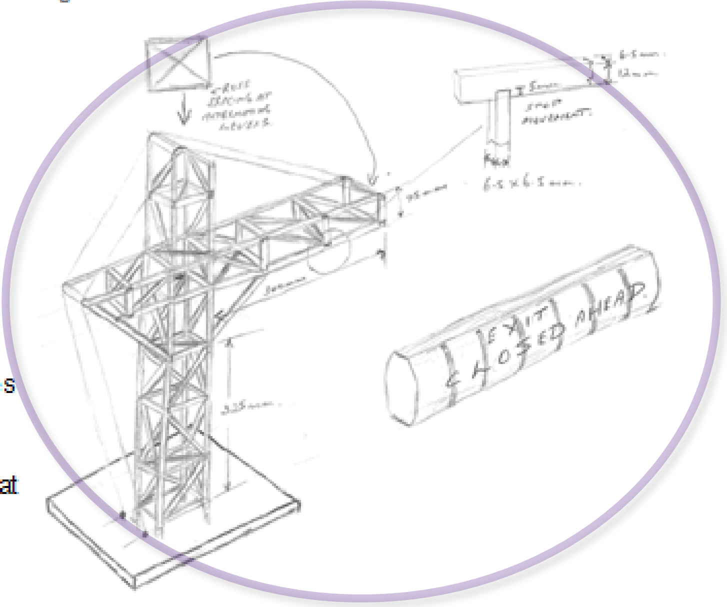
Options considered

The project team considered the fundamentals involved in existing freeway sign structures and tower cranes to develop ideas for evaluation and testing. The tower crane principle of using cables under tension to support heavy loads (see Figure 1) was applied to solve this problem. The cable is used in the proposed solution to transmit the compressive forces in the bottom cord of the beam and the inside of the column to other stronger sections of the structure. The tensile force in the cable is transferred to the structure through the struts as a compressive force which acts in the opposite direction to the reactive forces on the structure. The predicted solution in Figure 2 was selected because it was evaluated to satisfy the success criteria.

Figure 1: Tower crane

Alexandre Prevot, Liebherr 280EC-H, CCPL

Figure 2: Predicted solution



The investigations of like structures (tower cranes and road signs), testing of ideas, balsa material properties and frames indicates that this form of the structure (see Figure 2) would support the specified load without failure. A detailed analysis and calculations were completed to ensure the feasibility and safety of the proposed sign gantry as predicted. The predictions made were verified through testing conducted on the 15 September 2017, where the beam performance index provided a high result of 153.06

Recommendations

Based on the findings of this investigation, as documented in the folio (Part A), the project team provides the following recommendations for a cantilever variable sign gantry at the location as defined.

- Materials and fabrication

It is recommended that the cantilever variable sign gantry be fabricated off-site in two sections, the beam and column. This reduces the cost of transporting the structure to site and the lower cost and environmental and social impacts of a smaller crane to position the sections during construction. Detailed drawings will be provided that indicate the location of the column, the beam and the four braces that support the

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Communicating [3–4]

discerning decision-making about, and fluent use of,

- written and visual features to communicate about a solution
- language for a technical audience
- grammatically accurate language structures

The response demonstrates the thoughtful and astute choice of written and visual information to eloquently communicate the solution to a technical audience.

beam within the column frame. Two 10mm high-tensile galvanised cables will be mounted to the frame and foundation, and pre-tensioned to support the applied loads. The cables will add 7.5kg to the overall weight of the structure; however they will provide greater load carrying efficiency which provides a greater factor of safety than specified. This is recommended given the region B design wind speeds at the location and the position of the sign and framework above the busy arterial roadway. All bolt holes will be drilled prior to galvanising to reduce the risk of corrosion at the bolted assembly points. The use of mild steel angle as the material for fabrication of the gantry beam and column frames allows for welding off-site and hot dipped galvanising prior to installation. The zinc rich galvanised coating provides a low maintenance solution to the environmental conditions of the installation site due to its complete coverage of the base steel material and its cathodic properties. Steel was also selected because of its high economic value at all stages of recycling and because structures can be efficiently and accurately produced to specifications under controlled conditions to minimise waste and maximise strength. The slotted and aerodynamically shaped variable sign will be lifted into place and bolted to the frame after erection of the cantilever gantry framework.

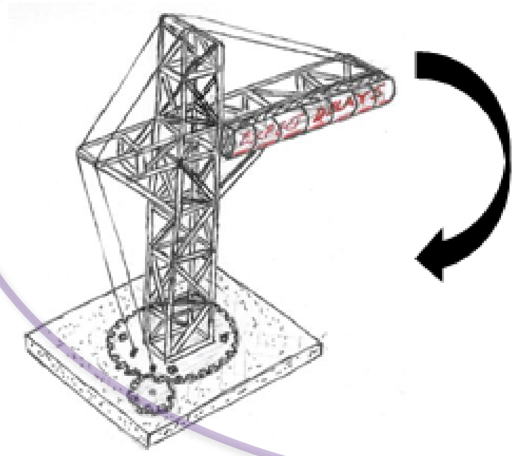
- Environmental considerations

The fabrication and zinc coating of the structure off-site requires less construction time on-site. This minimises the negative impacts of road closures, diversions or reduced speeds on the travelling public. Risks to construction workers are also kept to a minimum by the method of assembly and reduction of exposure to hazards i.e. vehicular traffic, exposure to weather, working at height and overhead lifting of materials by crane. Less time on-site reduces the impact to native habitat including the soils and vegetation. Disruption to the native animals is also kept to a minimum through the use of the recommended fabrication and installation methods.

- Future developments for consideration

An option for consideration is to develop the structure so that it can be assembled and erected parallel to the road and pivoted out over the roadway using a mechanical gearing, winch or pulley system and locked into position for use. This would also allow maintenance to be performed on the sign and structure away from the busy arterial roadway. To accommodate this modification to the proposed solution, changes would be required as indicated in Figure 3. A motor driven gearing system would be included that would swing the gantry away from the road for sign and gantry maintenance. The motor would be removed when work is completed and the gantry swung back into position above the roadway.

Figure 3: An option for Future development



Communicating [3–4]

discerning decision-making about, and fluent use of folio and referencing conventions

The response includes the folio convention of a reference list and a recognised system of in-text referencing.

Reference list

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