UBC Social Ecological Economic Development Studies (SEEDS) Student Report

UBC Sustainable Bollard

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University of British Columbia

MECH 457

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SHEARSOLUTIONS

MECH 457: UBC Sustainable Bollard

David Ko
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1.0 Objectives

The design objectives that we needed to address for the bollard project were to

- allow emergency vehicles quick easy access roadways
- minimize obstruction of vehicle path when bollard is collapsed
- assure pedestrian safety (minimal protrusions on bollard, to prevent tripping)
- provide a user friendly interface
- promote sustainable design (minimal parts replaced when collapsed) within UBC
- decrease total cost to UBC for bollards
- design a bollard that can adapt to current emergency tools (fire hydrant wrench)
- be aesthetically pleasing

2.0 Project Result

During the course of the last 8 months, we went from problem identification, which we identified deficiencies within the current bollards and the prototype that a previous MECH 457 team developed, to research and development of current alternative bollards, which includes designs using magnets, hydraulics and shearing devices. We then chose our design and developed the load barring mechanism called the lock ball. Finally we modified our initial design for the lock ball and manufactured a new alternative to the current shear cup road bollards that are used within the campus.

3.0 Considerations

The considerations that can be made for this project can be put into two categories

- Design considerations
- Test considerations

3.1 Design Considerations

During the course of constructing the prototype, several issues which had not been foreseen earlier in the design process were made clear. One of the biggest of these issues was the kinking of the cable during turning of the fire hydrant nut due to a small turning radius. The pipe that twisted the cables caused the cables to permanently kink and deform to what could eventually have become total failure of the cable. Also, the deformation of the cable caused the lock balls themselves to become eccentric as each lock ball was shifted off by a couple degrees in opposite directions.

The eccentricity of the lock balls led to one of the lock balls disengaging earlier than the other, causing the loads to be unequally distributed between the two lock balls (most of the load was placed on the lagging lock ball). A proposed solution to the kinking cables is shown in the diagram below:

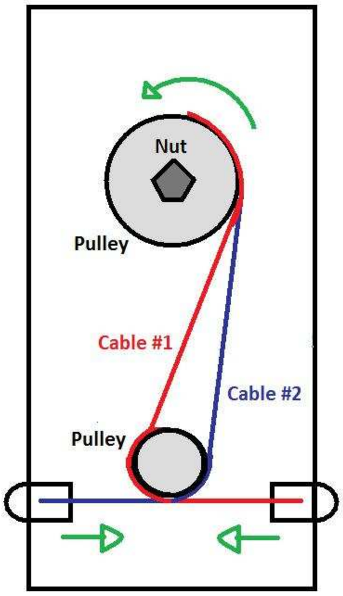


Figure 3.0 – Pulley System to Transfer Wrench Force

This pulley system would take advantage of the extra available space above the bollard and improve the alignment of the lock balls. Turning the hydrant nut in the direction shown in the previous figure would cause both of the cables to compress as indicated by the green arrows. The turning radius of the cables would now be long enough to avoid long term damage to the cables as well as straighten the positioning of the lock balls. Another advantage of this design is that it could potentially be cheaper as we would no longer require a long length of pipe and use a cable instead to cover the length of the nut and the lower pulley.

The most noticeable difference to the user would be that the hydrant nut would now be located at the side of the bollard rather than the top.

In the prototype design the holes for the lock ball guides (made from C-Channels) were oversized to make installation easier. Decreasing this hole size of the guides to closely fit the outer diameter of the lock ball would further increase concentricity at the cost of a more difficult installation.

Another problem that was noted during testing was that the base plate itself was bending under higher loads. This bending caused the cavities themselves to move. To remedy this it is recommended to increase the base plate thickness to at least ½ inch as well as decrease the overall dimensions down to 4.5 inches (originally 8 inches) by 14 inches. This would decrease the moment and thus the bending on the plate.

The calculations provided in this document are only valid as long as the cavities and angles of the lock balls remain relatively constant throughout loading. Ideally these suggestions would minimize deflections in the system but can not be fully proven unless another prototype is constructed.

3.2 Test Considerations

When we performed the prototype testing on the bollard, we only considered the minimum static load applied by a car to collapse the prototype. This is an important result for our prototype, but there is also the dynamic response to our model that was not determined. We did not consider the situation where a car induced an impulse force onto the bollard. These results to the dynamic loading could vary the reaction forces acting within the hinge and springs. This may also bring up other concerns for the area around the bollard, such as road destruction due to the force translated through the bollard and the fatigue life of the hinge and springs. Also, we tested our bollard in an ideal environment where natural elements (moisture, dirt, leaves, and snow) were not considered. Given that the cavity base and the shell are open to the environment, the affects of rusting, moisture and dirt on the coefficient of friction and the life on the springs and hammers were not experimentally determined. These factors that were not considered need to be tested to prove the complete validity of our prototype bollard.

As a future recommendation to a future MECH 457 design team, prototype deployment onto the UBC campus is needed to address the above concern. The exposure to the environment, under various weather conditions will give the bollard various situations that it must withstand and it will also give an indication on the effects of the environment on fatigue life.

4.0 Summary and Reflections

This project may have seemed like a simple project for a small group of mechanical engineering students, but as with everything in life, it is not that easy. The one of the biggest lessons learned from this project is that, communication is vital to success within any project.

The mechanical engineering department does provide adequate facilities and resources for students to use, the only problem with that is it is divided amongst almost 20 teams, developing their prototypes. So at times, shop time and materials become a big issue when availability was limited greatly. By consulting our client, UBC plant operations, we had access to their resources as well as the mechanical engineering departments. Some of the machining work was done by the resident welders at UBC plant operations sheet metal shop and some of the metal piping used for the prototype was given by the same shop; both at no cost to our budget.

Another lesson learned was that outside opinions are a great way of solving problems. Early in the development process, when we were trying to decide on which concept to continue the year with, we ran into some major issues on how to do the analytical analysis on magnets. Initially our simplified model seemed feasible to be considered concrete evidence, to go forth with the project. We were terribly mistaken, after a lecture about the brittle properties of magnets, and how dangerous it would have been to use magnets, it made our decision easy to go with the lock ball. By asking for help, it made our analysis and choice of concept much easier then before.

Finally, never under-estimate the time required to manufacture a part. A process that we thought would have taken an hour, actually took 4 hours. Always carrying a safety factor into manufacturing time is a good way of scheduling against real time progress.

There were two big turning points to the project. The first one was when we had a concept evaluation presentation, and we were having problems trying to decide between a modified shear pin designs and shear cup design. Dr. Mike Vander Loos approached us and asked if we considered a bollard, which had no breaking parts for the load barring mechanism. That insight from him made us go into a different direction from our original intentions. Another important point was when we found out that most of welding can be done in house by plant operations. It saved hours of time within a welding shop trying to get a product half as good as an experienced welder could do.

If we did the project again, we would delay when we started doing final prototyping and have some sort of design feedback loop incorporated into the manufacturing process. There were errors found with the design when we tried to manufacture the next part. By incorporating the loop, it would have been easier to re-design and build a more effective solution.

Appendices

1.0 Calculations

There are three methods of adjusting the impact force required to disengage the bollard. The first method is to increase or decreased the spring strength, the second being an adjustment to the angle of the base cavity chamfers, and finally an adjustment of the distance from the cavity base to the bollard shell (this will increase or decrease the compression length of the spring). Adjustment of the cavity base can be easily completed after construction of the bollard, so it is important that the angle of the base cavity chamfer and spring strength are correctly sized before construction.

These calculations will focus on the selection of the spring and cavity angles.

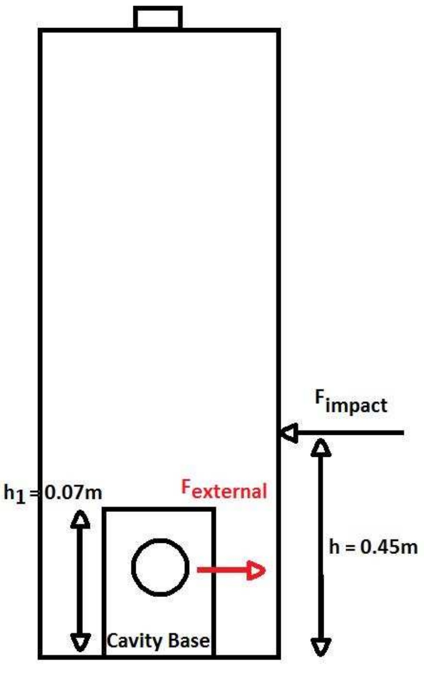


Figure X.1 – Force Diagram of bollard Shell and Lock Ball Interaction

The above diagram illustrates the impact force of a vehicle at a bumper height of 0.45m. This produces a resultant external force at the lock ball at 0.07m in height. As we can see the higher the impact force, the easier it is to forcefully disengage the bollard due to the moment.

Figure X.2 shows a diagram of the lock ball and cavity interaction. The true external force would be going into the page, but as the shape of the cavity is equivalent all the way around it is much easier to illustrate as it is. We can see that the external force causes a normal force, which oppose the friction force and spring force. For now, our desired impact force is to be 100kg, which seems to be a reasonable amount to take impact from vandals, but easily overcome by a moving vehicle.

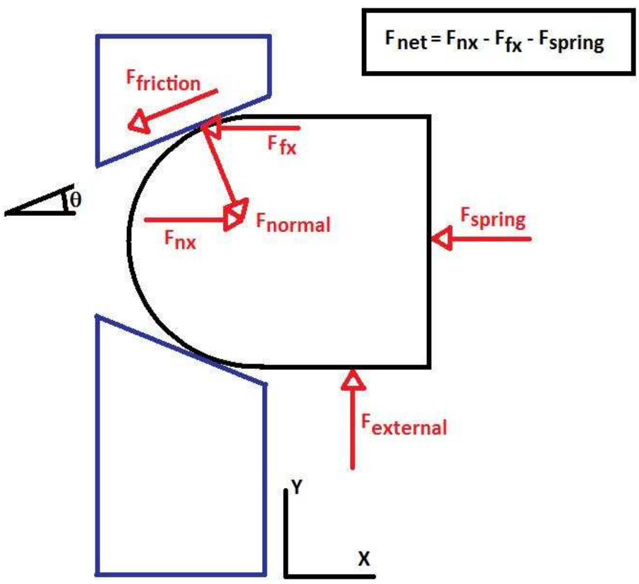


Figure X.2 – Force Diagram of Lock Ball and Cavity Interaction

The following relationships can be made:

$F_{spring} = K_{spring} + x_{\max}$ where $x_{\max}$ = 0.75 inches for max. spring compression of lock ball

$F_{nx} = F_{normal} * \sin\theta$

$F_{fx} = \mu * F_{normal} * \cos\theta$

We know that coefficient of friction μ for steel on steel (dry) contact is 0.6

μ for steel on steel lubricated is 0.16

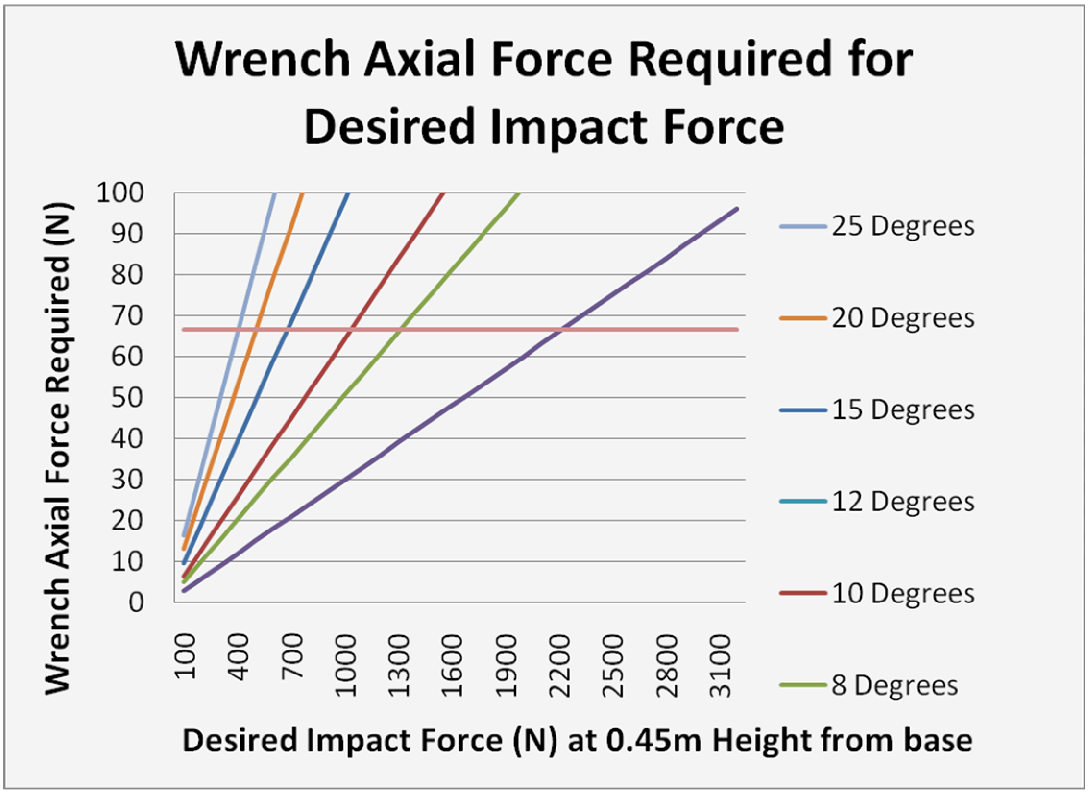
For the sake of testing for this prototype, we will be lubricating our steel to minimize our uncertainties for testing so a coefficient of friction of μ = 0.16 will be used.

Now the sum of forces in the x direction:

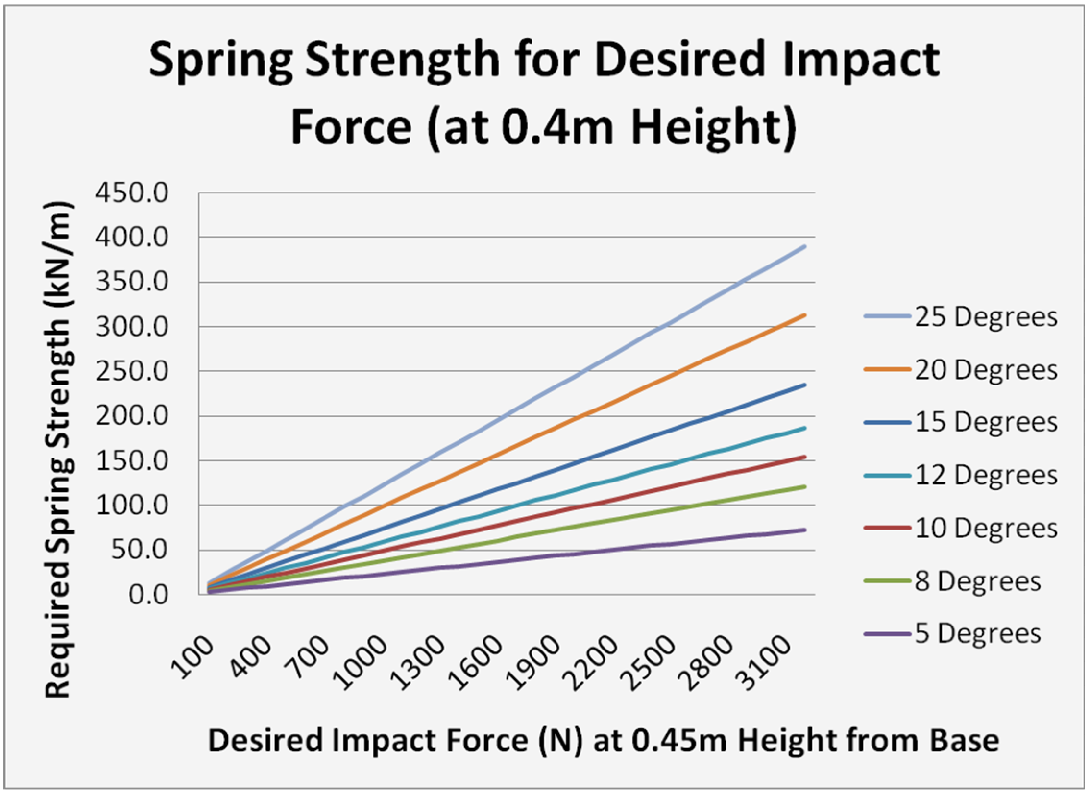
$\sum Fx = F_{nx} - F_{spring} - F_{fr}$

We know from this relationship that if the sum of the forces is positive, the spring will compress and the lock ball will move to the right. If the sum of forces is negative during impact, the lock ball will not compress at all.

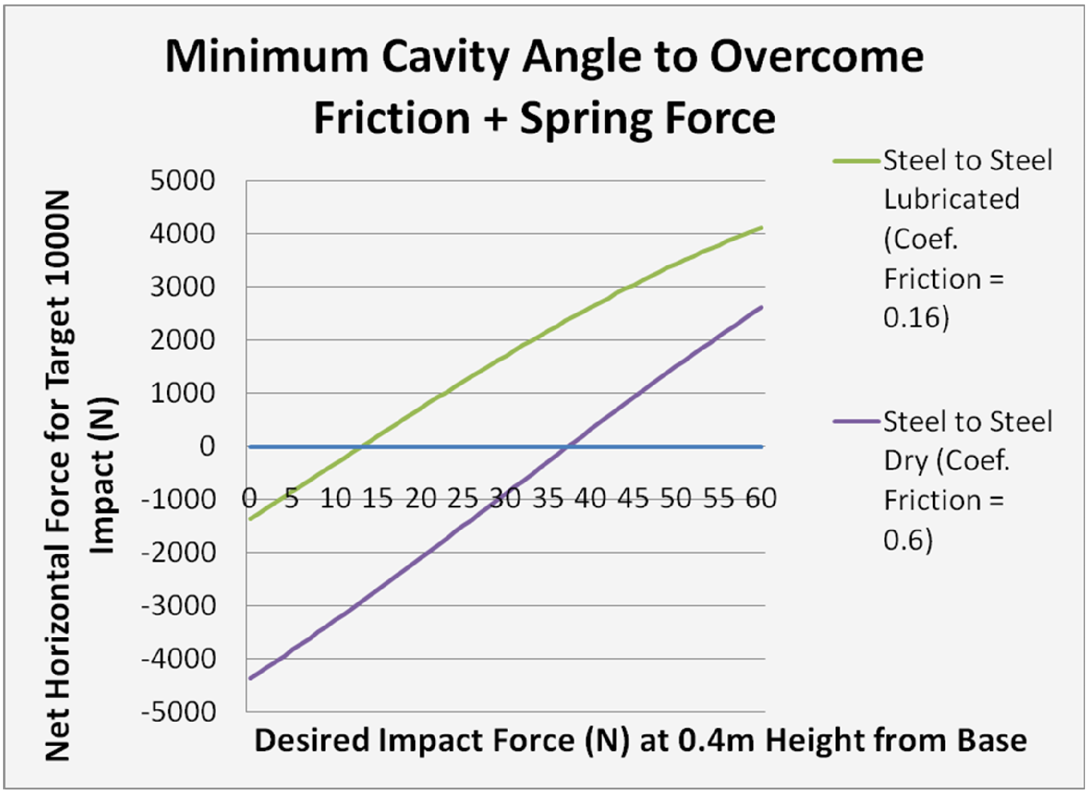
Using these relationships the following graphs and information has been produced. To do so a range of possible impact forces for a range of angles were plotted in excel. These impact forces were translated to a reactionary force on the lockball, F_{normal}, and then translated to F_{nx} and F_{fx}. From that we can determine the spring values since $F_{spring} = F_{nx} - F_{fr}$ if we want to size the minimum spring force. The following graphs are produced from this:



The figure above shows a horizontal line at 66.5N to indicate a comfortable axial load for a typical person (~15 lbs). The intersection of the lines corresponds to the maximum impact force limited to what would be comfortable for a worker to turn by fire hydrant wrench. These calculations are assuming lock balls are lubricated. From here we determined an angle of 10 degrees would be appropriate as this would allow for a 1000N impact force taken at bumper height.



This figure shows the required spring strength for our desired impact strength. In this case our desired impact strength is 1000N, and at 10 degrees we can see that we require approximately 42kN/m for both springs. So we would require 21kN/m for each spring. So the strength of our spring has now been decided.



Referring back to the force diagrams, we know $\sum Fx = F_{nx} - F_{spring} - F_{fr}$.

This graph shows the sum of the net horizontal forces, for an impact force of 1000N. The negative region of the net forces indicates that the normal force from the lock balls would be unable to overcome the combined frictional and spring force. The minimum angle to overcome these forces is where the line cross zero, which is approximately 10-11 degrees. The positive region indicates that the net force will be to the right, so that compression and disengagement can occur.

It should also be noted that when increasing the expected impact force, both curves shift to the left. This means that if we wanted impact force to be 2000 or 3000 N, the minimum angles would decrease further.

3.0 Project Costs

The final cost of our bollard project is shown in the catalogued information on purchased items. Since the Bollard Design Team did most of the manufacturing the costs are primarily from materials. The total expenditures amounted to $236.33

We an estimated the time it takes to manufacture all the components and assemble the prototype for one machinist to be a total of 4 hours. The wage of a prototyping machine as stated by PayScale Canada is $22.60/ hr. The total cost to completely manufacture this project is $326.73.

(Reference for the hourly wage)

http://www.payscale.com/research/CA/Degree=machinist/Hourly_Rate

<u>Catalogue information on purchased items</u>

Part & Description	**Quantity**	**Cost/Unit**	**Total Cost (CDN)**
1" Sch.40, Type C, Weld-On, **Steel Cap**	2	3.70	7.40
2-3/8" Dia., 1/4" Thick, **Steel Washer**	2	1.75	3.50
Type 304 Stainless Steel, 7x19 Strand Core, 1/8" Dia., **Wire Rope**	5 feet	0.254	1.27
1/8" Size, **Crimp Sleeve**	2	0.33	0.66
6" Long, 1.937" OD, .25" Wire Dia., **Box Grounded Compression Spring**	1	10.85	10.85
HSST 8"Width, 4" Depth,1/4" Think, **Rectangular Steel Tube**	31.50 inch Long	2.063	65.00
HSST 3.5"Width, 3.5"Depth, 1/4" Thick, **Square Steel Tube**	6 inch Long	1.67	10.00
4.25" Long, 2.25" Width, 2.1875 Depth, **Steel Block**	1	60.00	60.00
Hydrant Nut	1	~10.00	~10.00
6"Height Leaf, 5" Width Open, 0.18" Thick, Unfinished Steel Surface-Mount **Hinge W/O Holes**	1	12.50	12.50
Bollard Top Plate 8" Length, 4" Width, 1/4" Thick, **1018 Carbon Steel Plate**	1	7.23	7.23
Bollard Base Plate 4.5" Length, 4.5" Width, 1/4" Thick, **1018 Carbon Steel plate**	1	26.90	26.90
Sch40, 1" Dia., **Steel Pipe**	40" Long	0.1175	4.70
1/4" Dia**., Bolts**	11	0.188	2.07
1/4" **Nuts**	11	0.5072	5.58
1/4" Dia**., Fasteners**	4	1.6575	6.63
1/4" ID, **Washers**	4	0.195	0.77
1/8" Dia., Partially Threaded, 2" Long, **Fasteners**	2	0.635	1.27
	Total Cost		$236.33

4.0 Prototype Testing

For the final prototype testing, we deemed it necessary to measure the maximum load that our bollard can take before collapsing. We assumed ideal loading condition for our testing; the bumper height was taken as 12 inches from the ground, a translational force was applied to the front of the shell using a hydraulic jack until collapse. The following results were obtained.

Test #	Height (m)	Maximum Voltage (V)	Mass (kg)	Force (N)
1	0.6	1.575	99.0628695	971.8067
2	0.6	1.543	97.05016358	952.0621
3	0.4	2.219	139.5685761	1369.168
4	0.4	2.185	137.4300761	1348.189
5	0.3	2.556	160.7648854	1577.104
6	0.3	2.618	164.6645031	1615.359
7	0.3	2.588	162.7775913	1596.848
8	highest point	0.987	62.07939822	608.9989
9	highest point	1.104	69.43835424	681.1903
10	highest point	1.232	77.48917792	760.1688

As validation of data, we also performed the experiment at different heights from the ground. By doing the calculation, the average load that the bollard collapsed at was 100 kg of force, this was the result we were expecting to see.

5.0 Operations Manual

The following is a full description on the three operation modes for our Collapsible Bollard Design. The first operation mode is Vehicle Impact Mode (VIM), the second operation mode is Manual Disengagement Mode (MDM) and the third operation mode is Manual Re-engagement Mode (MRM).

Vehicle Impact Mode (VIM)
This mode of the bollard is passive. The bollard stands upright to the ground and remains standing until it receives an impact force to its front facing surface, one that would be generated by a vehicle's bumper. Upon impact, the bollard will fall to the ground. This will occur when the impact force generated by the vehicle is greater than the reaction from the dual springs in the bollard.

Manual Disengagement Mode (MDM)
This mode allows for the bollard to be manually disengagement from its upright position without the need of an impact force to its front facing surface. The operation procedures are listed below:

1) Place standard size fire hydrant wrench over the hydrant nut located at the top of the bollard.

2) Turn the fire hydrant wrench 90 degrees until the lock balls have conceded enough into the bollard shell, to allow for lowering of the bollard.

3) While maintaining the wrench at the torque position, lower the bollard to the ground.

4) Mechanism has been successfully disengaged from its upright position and should be resting on the ground.

Manual Re-engagement Mode (MRM)
This mode allows for the bollard to be manually re-engagement from its lowered position. The operation procedures are listed below:

1) Place standard size fire hydrant wrench over the hydrant nut located at the top of the bollard.

2) Slight lift the bollard from the ground so that it is easier to turn the fire hydrant wrench.

3) Turn the fire hydrant wrench 90 degrees until the lock balls have conceded enough into the bollard shell, to allow for lifting of the bollard.

4) While maintaining the wrench at the torque position, lift the bollard to its upright position. The lock balls should pop into place.
5) Mechanism has been successfully re-engaged from its lower position and should be upright to the ground.

Mech 457

Collapsible Bollard Project Proposal

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Word Count: 2407

Purpose of Proposal

This proposal has been prepared in response to a request from the SEEDS program of the UBC Sustainability Office to design a sustainable and collapsible bollard system. It is intended to identify the general requirements of the new bollard design and will outline deliverables upon completion of the project.

Abstract

The UBC Sustainability Office has submitted a project for the design of a new collapsible bollard design. A UBC Student design team has prepared a proposal in response to this request. This document provides an overview of the problem, design requirements, evaluation criteria, detailed project plan, budget and the required resources for the project. Primary requirements of the new design include the capacity to produce locally at a low cost, the ease of maintenance during the life cycle of the bollard, and having a minimal impact to the environment. An additional request from the client includes having minimal or no protrusions along the surface of the bollard for civilian safety. The currently in use bollard is imported from an American company on the East coast, and it is believed that there could be a potential market for locally manufactured bollards. This project currently has a $500 budget from the Department of Mechanical Engineering Department of UBC with additional tools and support from the UBC Sustainability Office. Upon completion of the project, we will deliver a fully functional prototype including all supporting documents, drawings, and calculations required for manufacture of the new bollard design.

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1.0 Introduction

1.1 Background

A bollard as shown in Figure 1.1 is defined as a vehicle obstruction device used to control traffic in areas designated for pedestrian use. Many different types of bollards exist in the market including static, automated and collapsible bollards. Collapsible bollards can be used in certain locations where emergency vehicles need to enter but other forms of traffic must be prevented.

A typical example of the collapsible bollard used at UBC supplied by Maxiforce (American company located in Eastern America at http://www.maxiforce.com) is shown in Figure 1.2. An aluminium cup within the collapsible bollard is sheared each time the bollard is knocked over by a vehicle. The bollard can then be re-used once the cup is replaced.

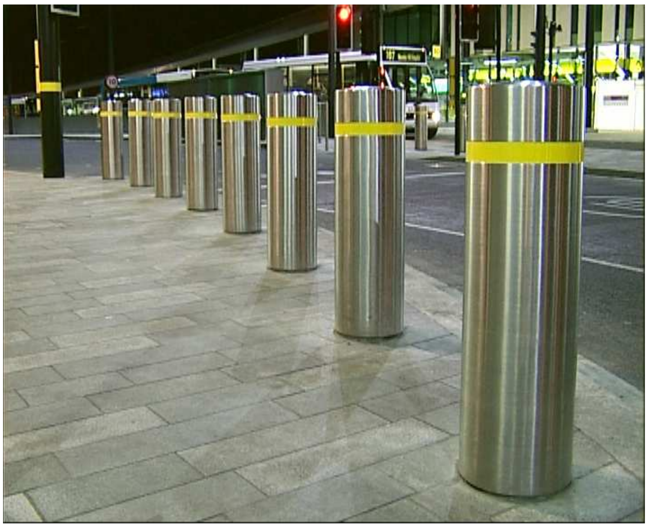

Figure 1.1 – Static Bollards preventing traffic flow towards a sidewalk

Figure 1.2 – Example of the Maxiforce Bollard currently in use at UBC

The current bollard system used at UBC is of relatively high cost. In previous years, a mechanical design team came up with a design proposal for this project. There were however a number of problems with their design which have prevented the client from manufacturing these bollards. One of these issues was related to safety as there were pieces that protruded from the bollard which pedestrians could trip over. This year the requirements have changed and a completely new design has been requested. Figure 1.3 illustrates the top and base section of the bollard where the base piece is below ground level within concrete. The top section of the bollard is the protrusion which will impede traffic, and will likely be hinged to the base section of the bollard. Both the top and bottom section of the bollard are to be designed for this project.

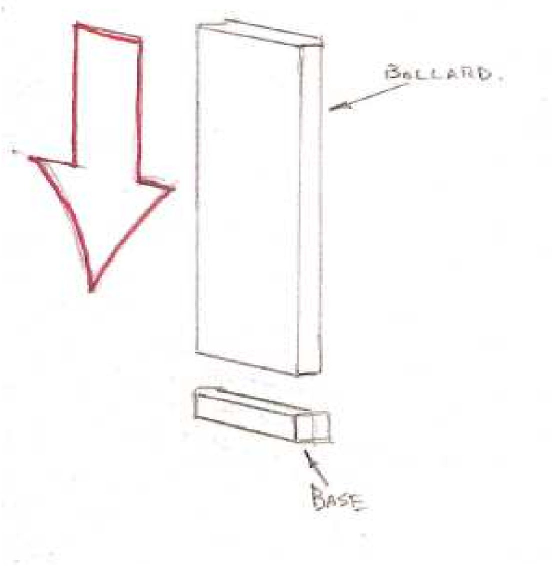

Figure 1.3 – Illustration of the base and top piece of a collapsible bollard.

The Manager of the UBC Seeds Program, Brenda Sawada, has requested a design proposal for a cost effective, collapsible and sustainable bollard. The primary user of this device will be Mike Giannias and his crew at the UBC Land and Building Services Department (LBSD). The designed bollards will be used throughout the UBC Vancouver Campus where pedestrian traffic is high and vehicle access is occasionally required. UBC Sustainability office and LBSD have both expressed an interest to have this design manufactured locally with the key focus on economic, environmental and social sustainability.

1.2 Scope

Regular meetings with UBC LBSD and the client will be established so that needs and requirements are fully understood. Research on previously discovered patents and new technologies will provide invaluable information during concept generation. Interviews with various emergency departments within the UBC area and other experts in the field will contribute to the research phase of the project. The next phase will be concept generation and concept refinement, which is based on the functional requirements, cost, and client/user input on current bollards.

When the final design has been proposed and accepted by the client, the prototyping phase will begin, with development of key components. In addition, experiments will be performed on the prototype to confirm that the functional requirements have been met. At the final phase of the project, proper documentation and a prototype will be presented and delivered to the client. The final objective will be to have the bollards used throughout the UBC Vancouver Campus and perhaps mass produced for commercial resale for other locations.

2.0 Requirements and Evaluation Criteria

The bollard should be based on a durable design, due to impacts from emergency vehicles while restricting access to other vehicles. The bollard design should be easy to set up from a collapsible position and also accessible to UBC crews through a manual disengagement mechanism. It will be sustainable with a relatively low cost and will be manufactured locally. With all this in consideration, the design should also consider aspects of economics, make it environmental friendly and socially sustainable.

Most important is the requirement for the bollard is to allow emergency vehicles to pass quickly. When collapsed, the bollard should not impede an emergency vehicle from passing through. The same situation must apply where the bollard is manually disengaged. The bollard shall also be designed for unidirectional impact from a vehicle. Another undesired quality for a bollard is to have protrusions along the exterior. The last student-designed bollard currently has an exposed protrusion near the base piece when the bollard is in its disengaged position which pedestrians may trip over and cause injury.

The greatest effort in terms of maintenance arises when a bollard has been knocked down by a vehicle. It has been stated by UBC Land and Building services personnel that commercial vehicles such as delivery trucks are the most responsible for knocking over the existing collapsible bollards. The collapsible bollard that is currently in use has an approximate cost of $1100 including shipping. Each time the bollard is knocked down an aluminium cup is sheared within the bollard. The bollard may be erected once the aluminium cups are replaced, but is a burden to working personnel as set up time takes approximately 30 minutes requiring two workers each set up.

This problem recites the need for a simpler method of erecting the bollard when it is knocked down. An excellent example of an existing patent that solves this issue is [United States Patent 5,441,359]. A hyperlink is provided in the references section of this proposal. In this patent a spring and latch mechanism are used to engage the base and post pieces of a bollard together. No pieces are broken or sheared when the bollard is knocked over and the bollard need simply be pulled back into position as the spring in conjunction with the cramming surfaces offers automatic reengagement. Re-erection of a bollard can be easily performed by one worker in a very short amount of time. A bollard design with a similar level of functionality and sustainability is ideal. Aside from this, there is little maintenance required on a bollard aside from an occasional re-painting every several years.

Lower costs may be attained by manufacturing the bollard locally. It would also be worthwhile to consider the feasibility of using of local manufacturers in preparation, to batch produce the new bollard design. Manufacturing locally not only produces benefits of a lower cost but also helps the local economy. Lastly, the aesthetics of the bollard are important to the final design. For market appeal, many users consider the aesthetics of a product as important as the functionality.

2.1 Requirements Summary:

- Allows Emergency vehicles quick easy access
- Minimal obstruction of vehicle path when collapsed
- Safety (Minimal Protrusions on bollard, to prevent tripping)
- Ease of use
- Sustainable design (minimal parts replaced when collapsed)
- Low Cost (cheaper than Bollards currently in use)
- Adapts to current emergency tools (Fire Hydrant Wrench)
- Aesthetics

2.2 Evaluation Criteria:

- Cost
- Installation Time
- Durability

With respect to the Evaluation Criteria, consider the following satisfaction curves.

Cost

The UBC mechanical department has supplied our team CAD $500 to design and developed a prototype. It should be expected that the client will be very satisfied with any design which is within the $500 supplied. Between the $500 budget and the $1100 cost of the current bollard, the satisfaction will most likely decrease at gradual rate. Once over the $1100 price of the current bollard, the satisfaction of the client will most likely decrease dramatically unless there is justification of the cost increase with new technological advancement in the design of the bollard.

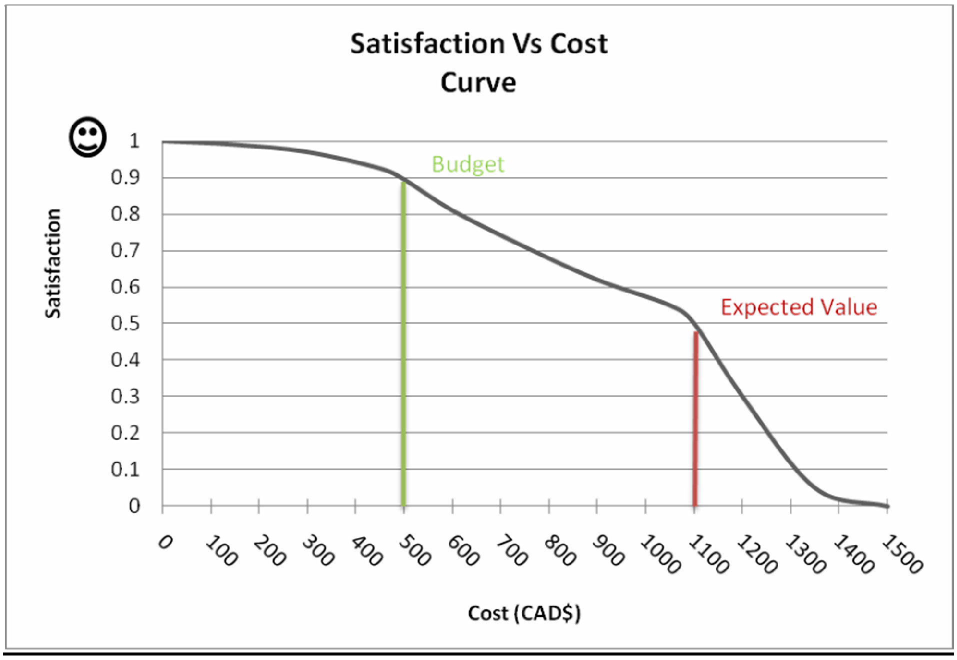

Figure 2.1 – Satisfaction vs. Cost

Installation Time

This category is referring to the amount of time required by a UBC Plant Operations maintenance worker to re-erect the Bollard that has been collapsed. Since the current design requires approximately 30 minutes to repair, then any new design that is relatively difficult to install (ie. takes more than 30 mins) will have satisfaction score close to zero. If any new design improves on the methology of re-erecting the bollard, a higher satisfaction is expected. Installation time between 5-15 minutes has a slow gradual decrease in satisfaction. From 15 to 30 minutes a more drastic decrease in satisfaction till it reaches .5 which will be the expect value of satisfaction for the original bollard to be set up. Anything passed 30 minutes is expected to provide a satisfaction a low satisfaction score.

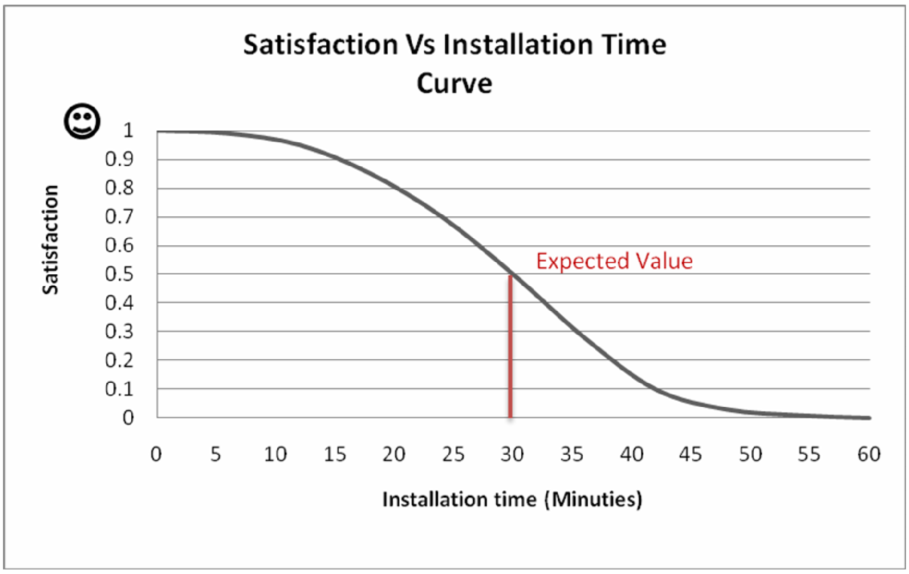

Figure 2.2 – Satisfaction vs. Installation Time

Durability

This category refers to the approximate lifespan of the Bollard's internal mechanism and shell. The existing design lasts roughly 10-20 years before requiring some maintenance work (repainting, sandblasting, and replacement of broken components). As long as maintenance is performed, the bollards are likely to last indefinitely. The satisfaction of the client is expected to be low if the new design is anywhere below the current lifespan of the Bollard. If the new design of the bollard is above the current lifespan of the Bollard, the client is expected to have a higher satisfaction. The satisfaction of the client is expected to gradually plateau after exceeding expected requirements.

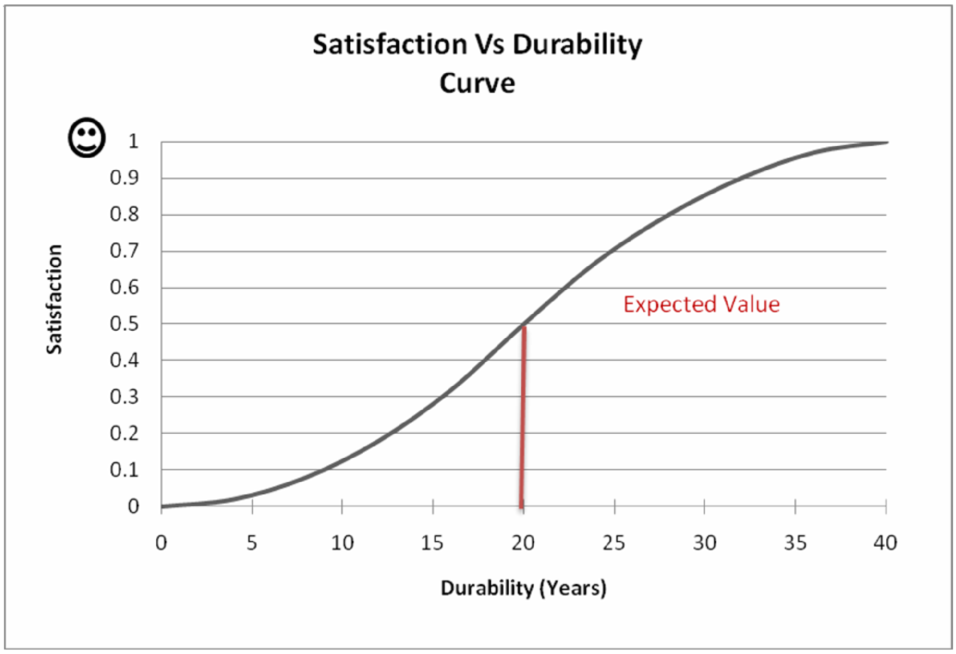

Figure 2.3 – Satisfaction vs. Durability

3.0 The Work Plan

The plan purposed for the bollard project will span from the beginning of October until the end of April. The plan consists of five phases.

- 3.1 Planning
- 3.2 Concept Generation
- 3.3 Evaluation
- 3.4 Technical Analysis
- 3.5 Prototype Development

3.1 Planning

The planning phase is as follows

- 3.1.1 Research Current Concepts
- 3.1.2 Interview with Sustainability Office
- 3.1.3 Proposal Report
    - Prepare draft of Proposal
    - Edit and Format Proposal
    - Hand in Proposal
- 3.1.4 Background Materials Report
    - Further research on current designs
    - Write Background Materials Report
    - Edit Background Materials Report
    - Hand in Background Materials Report

The milestones for this stage are handing in the proposal which is on October 3rd, 2008, and October 17th, 2008 for the background materials report.

3.2 Concept Generation

The Concept Generation phase is as follows

- 3.2.1 Research New Designs
- 3.2.2 Develop New Designs
- 3.2.3 Present conceptual designs to design team

The milestone for this stage is presenting concepts on the projected October 24th, 2008

3.3 Evaluation

The Evaluation phase is as follows

- 3.3.1 Apply pugh charts to preliminary designs
- 3.3.2 Evaluate competing designs with weighted decision matrix
- 3.3.3 Design Review Presentation
    - Create powerpoint for design review
    - Perform presentation
- 3.3.4 Concept Selection Report
    - Write draft of concept selection report
    - Edit report
    - Hand in report

The milestones for this phase are the design review presentation, which is on November 10th, 2008, and handing in the concept selection report, which is on November 14th, 2008.

3.4 Analysis

The Analysis phase is as follows

- 3.4.1 Conduct Experiments for loading specifications
- 3.4.2 Size Components
- 3.4.3 Develop Model
    - Develop Drawings
- 3.4.4 Technical Analysis Report
    - Write Technical Analysis Report
    - Edit report
    - Hand in report
- 3.4.5 Analyze Critical Function Part
- 3.4.6 Critical Function Report
    - Write Critical Function Report
    - Edit report
    - Hand in report

The milestones for this phase are finishing the technical analysis report, which due on December 15th, 2008 and finishing the critical function report which is due January 30th, 2009.

3.5 Prototype Development

The prototype development phase is as follows

- 3.5.1 Construct Casing
- 3.5.2 Construct Critical Function Component
- 3.5.3 Prototype Testing
- 3.5.4 Prototype Review
- 3.5.5 Final Report
    - Write Final Report
    - Edit report
    - Hand in report

The final milestones for the phase are the final report hand in, which is on April 29th, 2009 and the design celebration, which is on April 27th, 2009. The prototype must be finished before the design celebration.

4.0 Role of Team Members

The following is a brief description of the roles of the members of this design project. As this is not a large team these roles are not quite as rigid as outlined below.

Project Manager: Richard Situ

The Project Manager is responsible for co-ordinating and maintaining the proposed schedule of work to ensure project completion on time. Identifies and keeps track of project-specific issues and manages the scope of the project to ensure what was agreed to is delivered. Schedule meetings with design group and informs them of their deliverables.

Liaison: John Chang

The Liaison is the primary contact with the client and supervisor on behalf of the team. An important function of the Liaison is to set up meetings and address needs/questions on behalf of the group.

Editor: David Ko

The Editor is responsible for the final assembly of all documentation and delegates documentation tasks to group members and determines if documentation is appropriate for submission.

Technical Manager: Dan Horne

The Technical Manager obtains equipment and resources for the project. Other important tasks include maintaining drawings and calculations, and ordering parts and scheduling experiments. The drawings and calculations however will not be limited to one single team member within this design project.

5.0 Resources Required

Financial

UBC has committed to allocate $500 toward the design of a new Bollard. It is not likely that this budget will be exceeded judging by the final budget expenditures of the previous student group that worked on the bollard design. Most of the machining will be performed by the project group and many materials will be supplied by the UBC Land and Building Services Department.

Materials

Although it will not be know for certain until the design process has begun, it is reasonable to assume materials will be required such as: steel, fasteners, aluminum, springs etc.

Tools

A machine shop equipped with a lathe, milling machine, drill press, welding machine, as well as miscellaneous hand tools will likely be required.

The design effort will also require more specialized tools such as load sensors.

Workspace

The machine shop facility as well as the workbenches in the Rusty Hut 118 should provide adequate workspace to complete the project. However, the client has offered the use of workshop facilities if the need should arise.

Expert Advice

Regular correspondence with the client and faculty advisor will be necessary. In addition interviews with local Emergency Response personnel shall be conducted.

6.0 References and Appendices

Figure 1.1

ATG Acess - Products

http://www.atgaccess.com/products/ATGLiverpoolBollards6.bmp

Figure 1.2

Maxiforce bollard website – Product photos

http://www.maxiforcebollard.com/PhotoDetail.cfm?Photo=7

[United States Patent 5,441,359]

Collapsible vehicular barrier, George C. Filippi

http://www.google.com/patents?id=3i8iAAAAEBAJ&printsec=abstract&zoom=4&dq=traffic+bollard#PPA1,M1

Mech 457

Reference Materials Report

Dan Horne 81650046
David Ko
John Chang
Richard Situ

Date Submitted: October 17, 2008
Word Count:

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1.0 Introduction

This project involves the design of a bollard system with both an underground base and an aboveground collapsible section which can be viewed in figure 2.1. The bollard is expected to obstruct pedestrian vehicles from certain areas while allowing emergency vehicles to pass. Ideally the bollard would have no parts to be replaced each time it is collapsed due to vehicle collision and should also be cheaper to produce than the competing American bollard.

The initial bollard prototype will be used and test on the UBC campus by the UBC Land and Building Services Department (LBSD), with the potential for batch production if it performs to the client's desires. This new bollard design should be quick to set up once they are collapsed as the most frequent cases of bollard collapses are through vandalism or non-emergency vehicle collisions.

The objective of this report is to both demonstrate and increase knowledge of collapsible bollards in industry. Any relevant information regarding the new bollard design to fulfill the requirements previously stated will be displayed in this report.

This report will cover the use patterns of a collapsible bollard design as well as currently existing products and patents. Any existing standards and codes relevant to the bollard design will be highlighted followed by the key technologies that will be used to re-examine the group's initial requirements and evaluation criteria.

2.0 Use Patterns and Functionality

The following user interactions will be considered for the design:

- Installation
- Operation
- Maintenance

2.1 Installation

It is intended that the installation of the device is to be completed by one person. The design will consist of a main Bollard body and a Base that it mounts to. Therefore installing the device will likely involve: positioning the body onto the base, and inserting a pin and/or fastener to hold the body onto the base. The following diagrams illustrate this procedure.

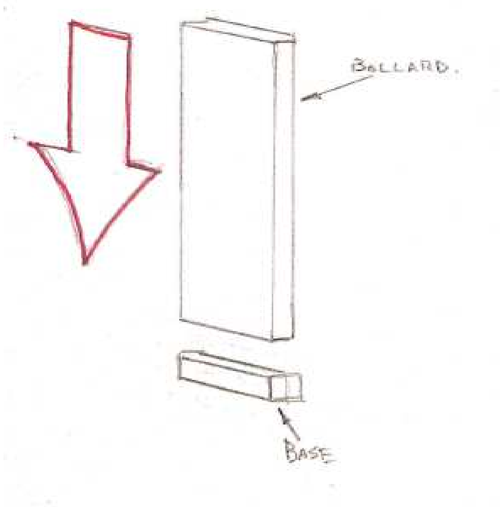

Figure 2.1 – Positioning the Bollard onto the Base

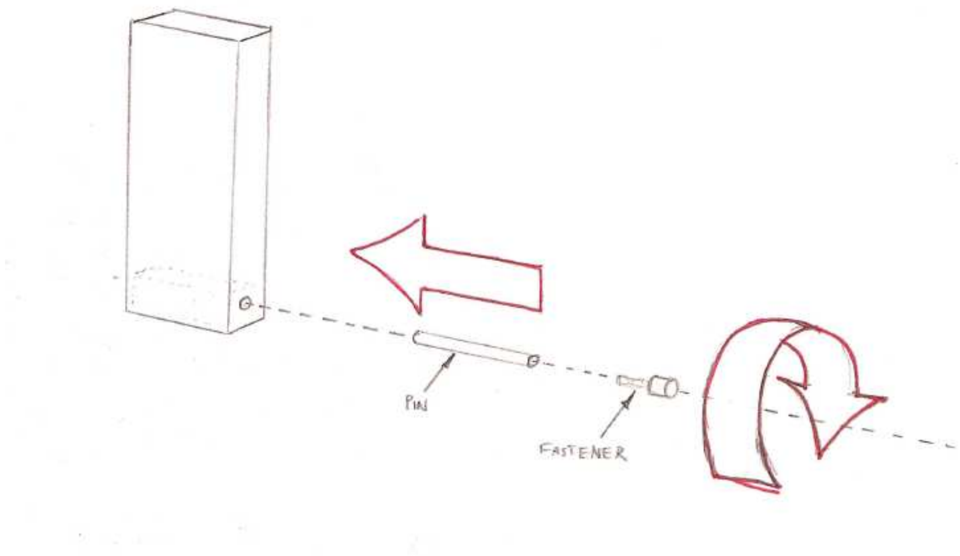

Figure 2.2 – Installing pin and/or fastener

2.2 Operation

In order to operate the device, it is expected that there be a method to engage a mechanism that allows the Bollard to collapse. It would be appropriate if this engagement interface conformed to the standard emergency tool that is currently used to operate the existing Bollards. Most of the user interaction with the device would likely be erecting and collapsing the bollard so a quick and simple method for set up would be ideal. A rough diagram is shown below, but the engagement interface will not necessarily be located on the face of the Bollard.

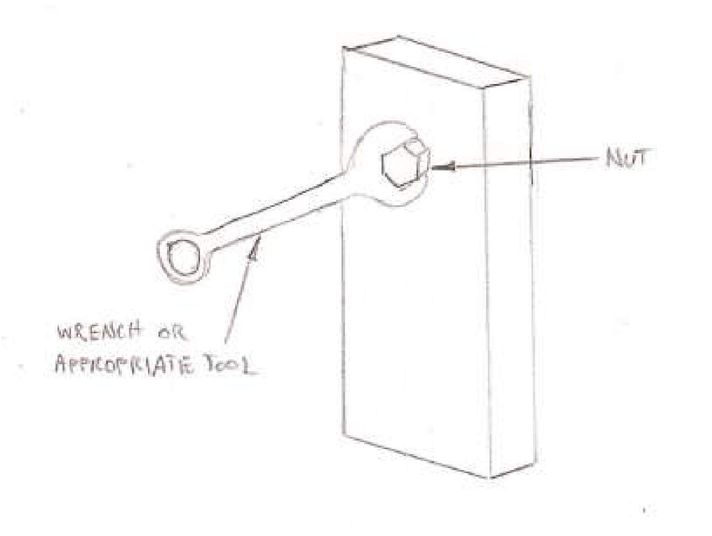

Figure 3 – Operating

2.3 Maintenance

Regular maintenance will consist of: replacing damaged Bollards, erecting fallen Bollards, and painting when necessary. The replacement procedure will be similar or identical to the installation procedure and the erection procedure will be similar to the operation procedure. If the bollard has been collapsed through collision of a vehicle, a piece of the bollard holding it in place may have been sheared off and would need to be replaced.

3.0 Existing Products

There are several existing products currently available that can achieve the desired function. The most relevant type of product to achieve the desired function is the fully mechanical collapsible bollard type. An American company called MaxiForce Traffic Control Bollards currently supplies the collapsible bollards used at the UBC Campus. Consider the following product from them:

Figure 3.1 – MaxiForce ™ Collapsible Bollard

This bollard has a manual disengagement mechanism and can be brought to and from a collapsed state relatively quick as long as the operator has an Allen wrench. An aluminium cup within the collapsible bollard is sheared each time the bollard is collided with a vehicle, although it can be re-used once the cup is replaced. The Bollard shown in Figure 3.1 however currently does not meet all of the customer needs. Some of the needs that aren't being met by the current design include:

- The Bollard is not manufactured in the East Coast of America, increasing costs.
- A sudden impact from a vehicle shears aluminum cups within the bollard and requires much time to replace. The Aluminum cups must also be ordered from Maxiforce.

Positive aspects of this product include:

- Manual collapse and erection of the bollard is quick and easy as long as correct tools are on hand.
- Very well protected to ambient environment as all components are fully encased.

4.0 Relevant Patents

All the relevant patents that were found for collapsible bollards, deal with the highest stressed area, the collapsing mechanism.

The first patent that will be analyzed is similar to the design of the current style of bollards used around UBC.

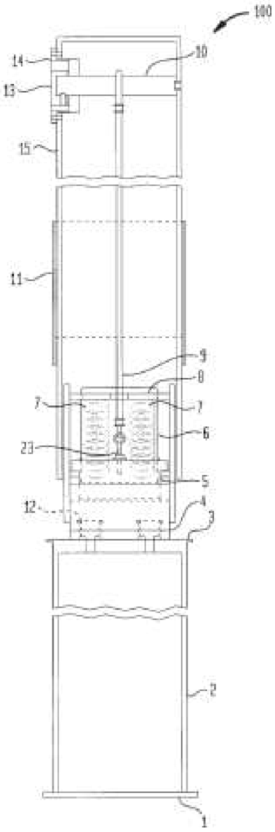

Figure 1: Current Design

The above design highlights the use of shearing cups. The locking mechanism retractor (10) pulls on a spring supported plate. The plate (23) pushes down on the machined base, so that the bollard is locked in. It will only collapse, while locked in, when the shearing cups (12) reach their fracture stress limit. When the locking mechanism retractor is turned with a fire hydrant wrench, the plate is lifted against the springs, and the shearing cups will not be the load barring components; thus the bollard can freely be collapsed. This similar design is still currently in use because of its ease of use and little maintenance required. The one fault of this design is the replacement of shearing cups after any sudden impact. The cost of each shearing cup can accumulate when specially ordered from a supplier.

The next design has not been seen in the market from some of the major traffic bollard companies.

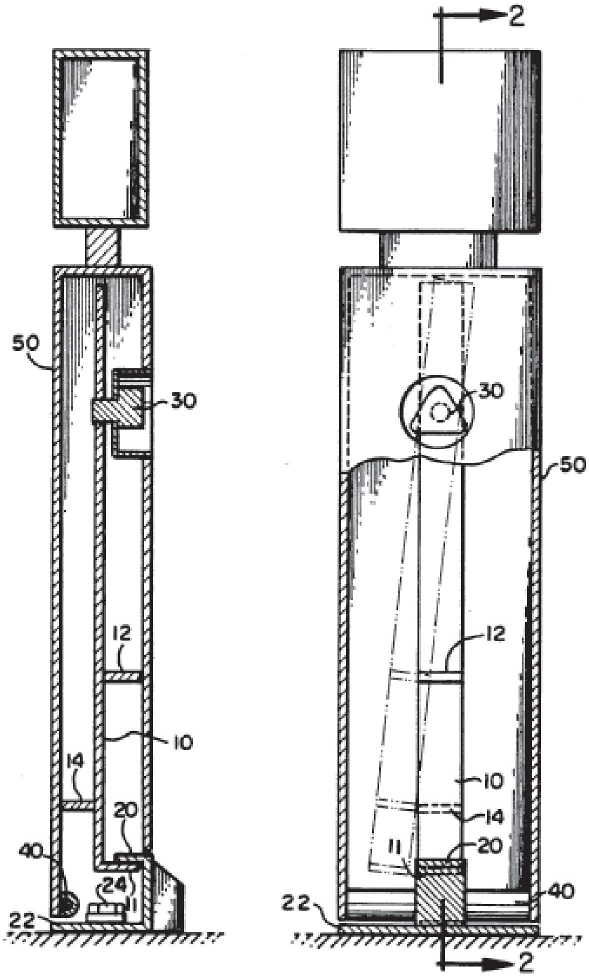

Figure 2: Swing Arm Bollard

The swing arm style is similar to the current in use design with respect to aesthetics. The swing arm however uses an L shaped bar as its load barring component as seen in Figure 2. The major flaw with this design of bollard is the replacement of the L shaped bar after an impact. The whole bollard assembly would have to be taken apart, to get to the L shaped bar. The bollard itself would have to undergo continual fatigue analysis, even if the bollard was not fully collapsed. For the normal operation of the bollard, more additional funding is needed for maintenance.

The final design takes a more automated approach to bollard design.

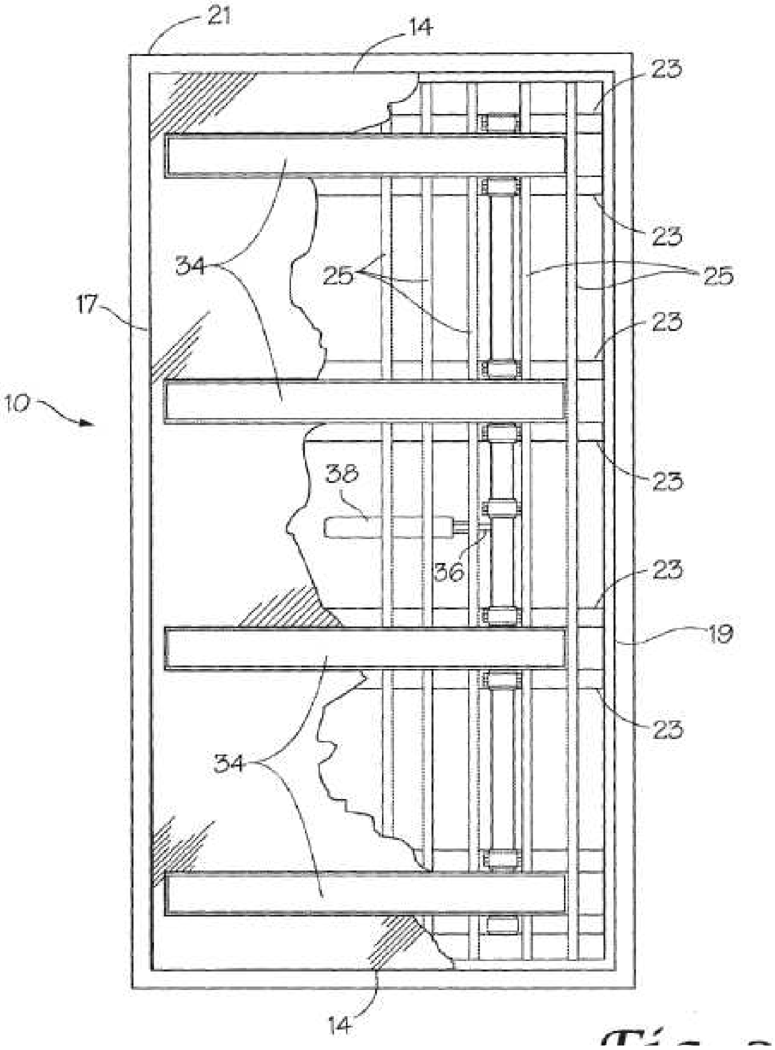

Figure 3: Automated Bollard

A motor is connected to the main power transmitting shift. At the position of each bollard, there is a cam positioned at the base of the bollard. The motor will turn until the bollard is fully stood up. A pneumatic cylinder (38) is attached to one of the cams to control the amount of rotation. One large issue with the system is its' complexity. If one component in the assembly goes down, more down time is required to repair it. Also, some of the components may need to be specially made, so it may become more expensive than the previous patents analyzed.

All the patents analyzed above are very specific on their breakaway mechanisms. When designing a brand new bollard, we can use the existing solutions, but each one can be modified in a way that a new solution can be developed without infringing on the past patent.

5.0 Standards, Codes, and Certifications

Three primary sources were used to research the standards and certification requirements for collapsible bollards. The client and user, the current supplier Maxiforce Traffic Control Bollards and various online databanks were the sources used to determine the types of codes, standards and certification requirements need for our design.

5.1 Client and User

The client Brenda Sawada and Kelly Coulson were asked about the key standards that might be imposed on the bollard devices at UBC. Both Brenda and Kelly recommended that any questions regarding the key standards should be directed towards Mike Giannias.

A similar question was also addressed to the primary users of the device (Mike Giannias and the UBC LBSD crew). Mike said, “We do not have any standards on campus for these types of bollards. They have been a campus fixture for years and this is the style we have been using. Like mentioned in the initial meeting, change and design would be a good thing.”

5.2 Current Supplier – MaxiForce Traffic Control Bollards

An email was also sent to the current supplier MaxiForce Traffic Control Bollards. A specification sheet was received from the company which indicated certain standards that were followed during the manufacturing and design of their collapsible bollard. A few standards are listed below, that specificy the type of materials and processing used in their design.

2.1 ASTM A53/A53M-04a **-** Standard Specification for Pipe, Steel, Black and Hot-Dipped, Zinc-Coated and Welded and Seamless

2.2 ASTM A366 **-** Standard Specification for Steel, Carbon, Cold-Rolled Sheet, Commercial Quality

2.3 ASTM A500 - Standard Specification for Cold-Formed Welded and Seamless Carbon Tubing in Rounds and Shapes

5.3 Codes, Standards and Certification Databanks

Our research through the various databases showed that there were no standards, codes or certification requirements for the key search words: bollards, collapsible bollards, vertical posts or posts. With this being the case, there were other standards to take into consideration when designing this prototype. Several key online websites were used to search for relevant standards for design and manufacturing.

What was found in the Canadian Standard Association website www.csa.ca and the International Organization for Standards website www.iso.org , were various standards on technical drawings, dimensioning, tolerancing, processing and components. Some of these standards will be used with further review during the design process. The list below represents a few of the standards that will be considered.

3.1 CAN3-B78.1-M83 (R2002)- Technical Drawings - General Principles (55 pages)

3.2 CAN/CSA-B78.2-M91 (R2002) - Dimensioning and Tolerancing of Technical Drawings (139 pages)

3.3 B97.1-1970 (R2002) - Standard Tolerances for Linear Dimensions, Inch and Metric (19 pages)

3.4 B97.2-1970 (R2002) - Interpretation of Limits and Tolerances (14 pages)

3.5 B97.3-M1982 (R2002) - Tolerances and Standard Fits for Mating Parts, Metric Sizes (49 pages)

6.0 Key Technologies

The key technologies pertaining to traffic bollards are closely related to manufacturing automation and simple load barring components. The concept of conveyer belts and power transmission can be clearly seen in the automated bollard patent. As for load barring components, a wide range of impact situations can be accommodated by the material of the shearing material within the collapsible bollard. After spending some time reading about electronic automation, the patents listed above can be further developed into more sophisticated solutions. The automated bollard can be modified to have a proximity sensor with a RFID chip, so as a emergency vehicle approaches it, the motoring system will engage and collapse the bollard automatically, versus someone turning it on and off from a control room, for example. Simple load barring components are highly dependent on the shape of the component and material chosen. With further research into the structural integrity of new materials, cheaper and stronger materials can be used in the future, depending on the loading conditions.

7.0 Reasses Requirements and Evaluation Criteria

The bollard should be based on a durable design due to impacts from emergency vehicles while restricting access to other vehicles. The bollard design should be easy to maintain and also be accessible to UBC crews through a manual disengagement mechanism. It will be sustainable with a relatively low cost and will be manufactured locally. Additionally, both the top post and the lower base of the bollard are to be designed for this project. With all this inconsideration the design should also consider aspects of economics, environmentalism and social sustainability.

Most obvious of the bollard is the requirement for it to allow emergency vehicles to pass quickly. When collapsed, the bollard should not impede an emergency vehicle from passing through. The same situation must apply where the bollard is manually disengaged. The bollard shall also be designed for unidirectional impact from a vehicle. Another undesired quality for a bollard is to have protrusions along the exterior. The last student-designed bollard currently has an exposed protrusion near the base piece when the bollard is in its disengaged position which pedestrians may trip over.

The greatest effort in terms of maintenance arises when a bollard has been knocked down by a vehicle. It has been stated by UBC Land and Building services personnel that commercial vehicles such as delivery trucks are the most responsible for knocking over the existing collapsible bollards. The collapsible bollard that is currently in use is supplied by a company called Maxiforce with an approximate cost of $1100 including shipping. Each time the bollard is knocked down an aluminium cup is sheared within the bollard. The bollard may be erected once the aluminium cups are replaced, but is a burden to working personnel as set up time takes approximately 30 minutes requiring two workers each set up.

This problem recites the need for a simpler method of erecting the bollard when it is knocked down. An excellent example of an existing patent that solves this issue is [United States Patent 5,441,359]. A hyperlink is provided in the references section of this proposal. In this patent a spring and latch mechanism are used to engage the base and post pieces of a bollard together. No pieces are broken or sheared when the bollard is knocked over and the bollard need simply be pulled back into position as the spring in conjunction with the cramming surfaces offers automatic reengagement. Re-erection of a bollard can be easily performed by one worker in a very short amount of time. A bollard design with a similar level of functionality and sustainability is ideal. Aside from this, there is little maintenance required on a bollard aside from an occasional re-painting every several years.

Lower costs may be attained by manufacturing the bollard locally. It would also be worthwhile to consider the feasibility of using of local manufacturers in preparation, to batch produce the new bollard design. Manufacturing locally not only produces benefits of a lower cost but also helps the local economy. Lastly, the aesthetics of the bollard are important to the final design. For market appeal, many users consider the aesthetics of a product as important as the functionality.

2.1 Requirements Summary:

- Allows Emergency vehicles quick easy access
- Minimal obstruction of vehicle path when collapsed
- Safety (Minimal Protrusions on bollard, to prevent tripping)
- Ease of use
- Sustainable design (minimal parts replaced when collapsed)
- Low Cost (cheaper than Bollards currently in use)
- Adapts to current emergency tools (Fire Hydrant Wrench)
- Aesthetics

8.0 References

Figure 1.1

ATG Acess - Products

http://www.atgaccess.com/products/ATGLiverpoolBollards6.bmp

Figure 1.2

Maxiforce bollard website – Product photos

http://www.maxiforcebollard.com/PhotoDetail.cfm?Photo=7

9.0 Appendices

Mech 457

Concept Alternatives

David Ko
John Chang
Richard Situ

Date Submitted: November 20, 2008
Word Count: 4462

Purpose of Proposal

The conceptual alternatives report has been prepared to demonstrate the user's requirements and necessary functions. This report will show the methods used to implement these functions into several design concepts. Each concept will be evaluated based on the evaluation criteria outlined in the report.

Abstract

The purpose of this project is to develop a cost-effective, sustainable, and collapsible traffic bollard. The primary functions of the user requirements include the ability to prevent or limit access to unauthorized vehicles yet allow emergency vehicle access. Additionally a separate manual disengagement mechanism is required operating personnel.

The primary concepts we have generated are listed as follows: cable hook concept, spring force concept, lock ball concept and shear pin concept. The report will validate how each concept satisfies the functional requirements by use of several screening techniques.

The concept selection has been narrowed down to three viable concepts, one being a low risk and low uncertainty design, and the other two being higher risk but potentially higher performing designs. It is planned to proceed by further refining the negative aspects of each of these concepts as well as using verification methods such as FEA, FMEA, stress and fatigue analysis.

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1.0 Introduction

The purpose of this project is to design a collapsible bollard which can satisfy all the functional requirements the client has outlined in their proposal. The following is a list of key functions that will be the main focus our design:

- Prevent or limit access to unauthorized vehicles
- Allow emergency vehicles access
- Separate manual disengagement mechanism for a worker

These three functions will have the most influence in determining the final design and are shown in the function-structure diagram.

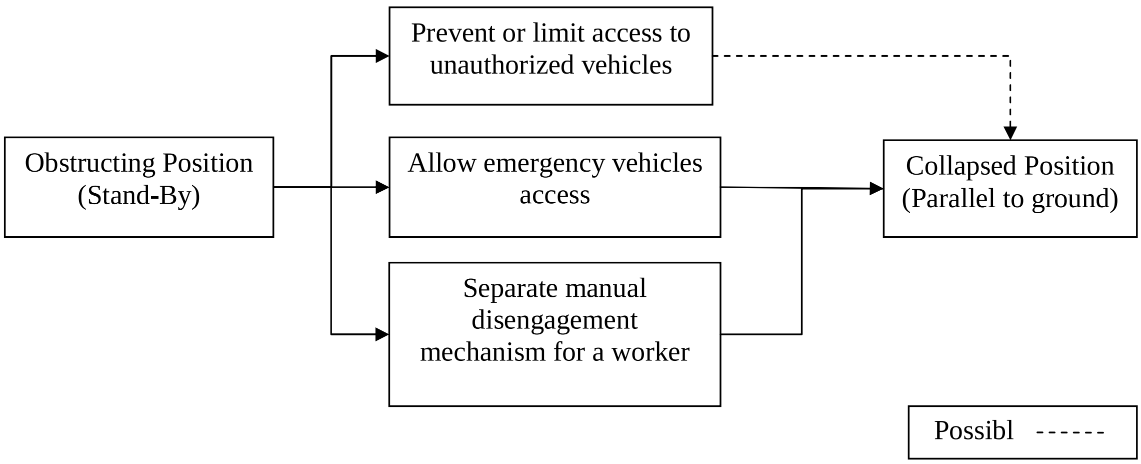

Figure 1.1

The primary function of the bollard design is to prevent or limit access to unauthorized vehicles. This function can be performed without direct user interaction. The bollard should be constructed of a durable material and manufactured so that it can withstand a certain amount of impact force before collapsing to meet this function.

Another important function the bollard design must perform is to allow emergency vehicles access to an area. This function should be performed without direct user interaction but may function more easily if there was interaction from a user. A sensor system within the bollard could activate its disengagement mechanism or a vehicle could directly impact the bollard and collapse it.

If a separate manual disengagement mechanism for a worker is a needed, this function would require direct interaction with the user. The use of a special tool or electrical device could allow the bollard to be manually collapsed by a worker. With these key top-level functions implemented into our final design, the majority of the design requirements should be met.

3.2 Failure Modes and Effects Analysis

2.0 Benchmarking

An example of an existing product relevant to the project is the Maxiforce Traffic Bollard.

Figure 2.1 – Maxiforce Collapsible Traffic Bollard

They are the current supplier of bollards for UBC and are an industry leader for collapsible bollards. The Maxiforce Traffic Bollard will be considered the benchmark design for this project, with evaluations performed relative to the performance of this product as this device has met all the functional requirements.

This device has an internally built manual disengagement mechanism within the bollard structure. The use of a Hydrant-Wrench allows a worker to manually lower a bollard to the ground without having it engage a vehicle. There is a breakaway safety feature that allows emergency personnel immediate access by impacting the bollard. Two unique inserts located at the base of the bollard are designed to shear when impacted by a vehicle.

This allows the vehicle access without causing significant damage to the bollard or vehicle. The breakaway feature is a component that satisfies one of the key functions of this project but also prevents it from satisfying another. For clarification, the function of preventing or limiting unauthorized vehicles access cannot be satisfied, but function of emergency vehicles gaining access can.

An estimate of the performance for the Maxiforce Traffic Bollard against the following evaluation criteria is shown below.

- Sunk Cost (Manufacturing/Raw Materials)
  - The cost for UBC to purchase this bollard is roughly USD $1100. This is considered relatively expensive for the client and the value of this criterion is very high.
- Variable maintenance cost
  - The cost to replace the breakaway inserts upon vehicle impact is approximately USD$20. More importantly, the labour costs associated with replacing these inserts is far greater than the cost of the inserts themselves. Variable cost is a criterion which is considered an important as the sunk cost of the bollard since the design is to be built with sustainability in mind.
- Setup/Disengagement Time
  - This device ranks exceptionally high in this criterion due to its fast and easy disengagement mechanism. The value of this criterion is important to user as less time spent on setup/disengagement means reduces labour costs.

- Durability
    - Another high ranking value for this device since the breakaway inserts is designed to limit the impact on the bollard. Durability can be seen to have a high value in the overall design since it can be related to sustainability. A longer life cycle for this device would also entail lower replacement and maintenance cost.
- Effectiveness
    - Due to the ability to choose different strengths of breakaway inserts, this bollard rates highly in its effectiveness in impeding or allowing vehicle access. This is another criterion of high importance to the client because the main purpose behind a bollard is to control road traffic effectively.
- Ease of Use
    - The Maxiforce Traffic bollard is very easy to operate and use. This can be show in its quick setup and disengagement time. This is another criterion which may have a high value for the user but not necessarily for the client.
- Safety
    - Since all mechanisms are built to function internally, with the exception of the hydrant nut, this device can be considered very safe. With the breakaway insert designed to shear at the bottom of the base, the bollard does not have any other parts designed to fail. Safety can be considered to be important in all designs, but in this project its value may not be as high since the level of danger is not expected to be high.

The uncertainty of the values for all the evaluation criteria can be relatively dependent on the different requirements of the client and user.

3.0 Concept Generation

The bollard design is broken up into 2 different parts.

- Manual engagement/disengagement
- Load barring break away mechanism

3.1 Manual engagement/disengagement

These mechanisms allow the bollard to be collapsed and re-engaged at the discretion of the personnel.

Tensioned Line

For any concept that involves a rope or chain that is in tension, a lockable attachment device must implement. This allows easy disengagement of the bollard

Comment [RS1]: http://www.sdfdtraining.com/PDF/Truck_Manual/images/100_0519.JPG

Figure 3.1 - Rotating Carabineer

This device can be easily released by opening the carabineer and releasing the tension on the line by being detached from the breaking mechanism.

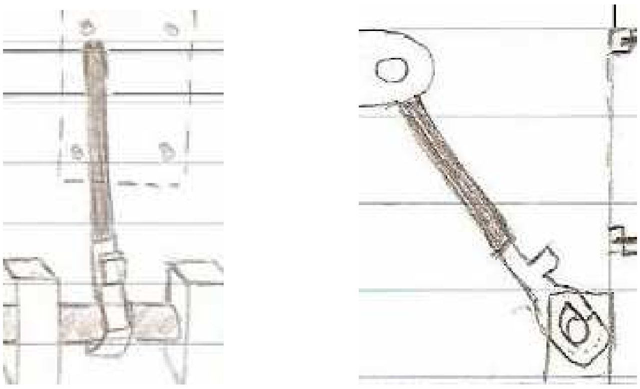

Figure 3.2 - Tensioned line release mechanism

Scissor Lift

The scissor lift is modeled after a typical car jack. It utilizes a power screw to transmit rotational power to vertical motion.

Comment [RS2]: http://www-c.inria.fr/gamma/OBJECTS/SCHNAUZER/MECHANICAL/31-car-jack.jpeg

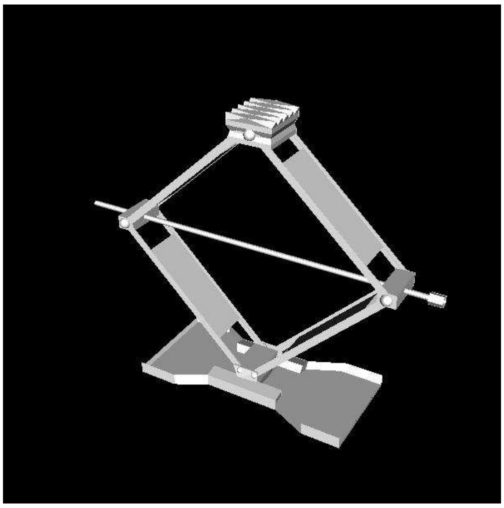

Figure 3.3 – Typical Car Jack

The scissor lift uses the same principles as the car jack, but inverts everything for the purpose of lifting.

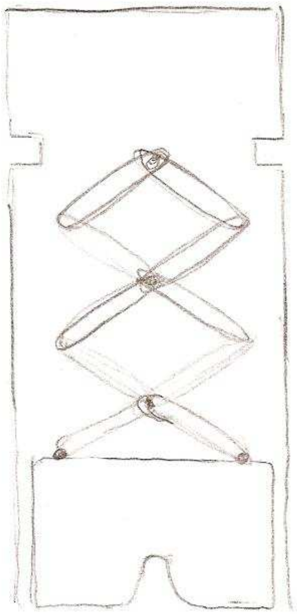

Figure 3.4 - Scissor Lift

The power screw is turned so that the scissor design is contracted. The end of the scissors is connected to the load bearing mechanism. This in turn will raise it to the unlocked position. Figure 3.4 illustrates this.

Linkages

Linkages allow for transmission of translational motion of an object connected to the end of a linkage system from rotational motion of a nut. An example of this can be seen in figure 3.5

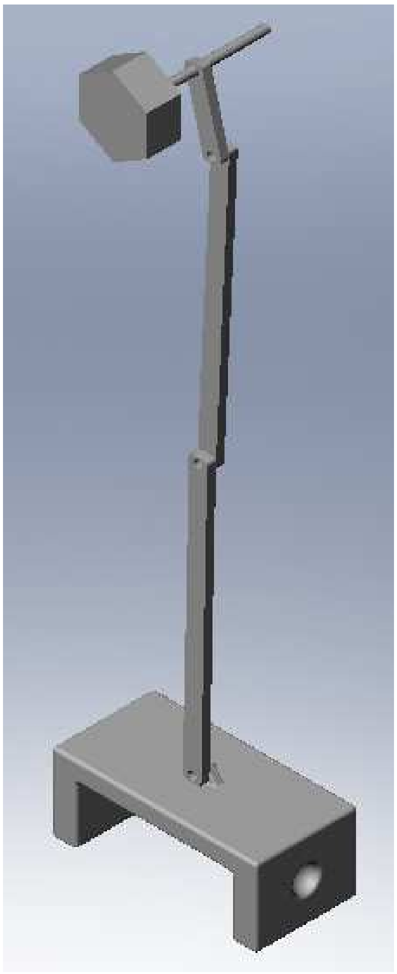

Figure 3.5 - Linkages used to raise block

All other concepts can be found in appendix.

3.2 Load Barring Break Away Mechanisms

The following concepts are mainly concerned with barring the force of a vehicle hitting the bollard.

Shear Pin

The shear pin is designed to handle shear at a certain load. The load at which this occurs is dependent on the material used and the grooves applied to the pin. The groove generates a stress concentration, so that the pin will fail at a designated spot. This can be seen in figure 3.6.

Comment [RS3]: http://www.meyerinsulation.com/images/accessories/Shear%20Pin.jpg

Figure 3.6 - Grooved shear pins

Frictional load barring

In frictional load barring, the friction force is generated by an applied normal force. This is illustrated in figure 3.7.

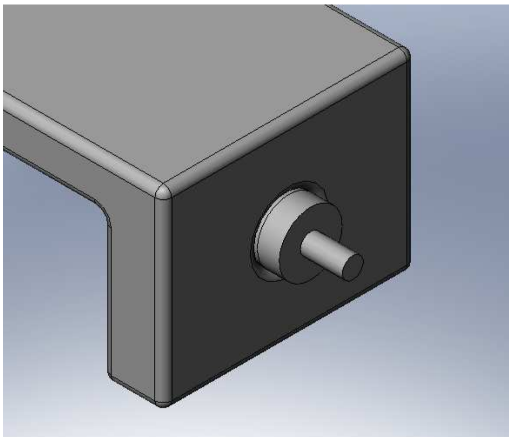

Figure 3.7 - Frictional Force Locking

The hammer that is in direct contact with the block creates a friction force which can be used as the bracing force from the vehicle.

Magnet

Magnets create an attractive force that can be used as the resisting force to the force generated by a car collision. An arrangement of this can be seen in figure 3.8.

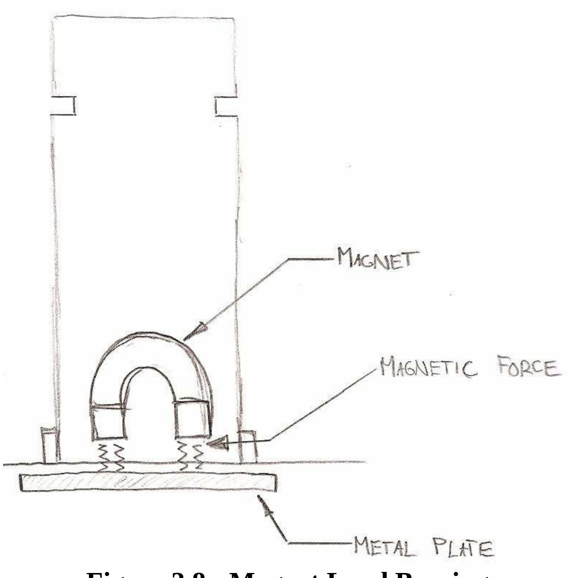

Figure 3.8 - Magnet Load Barring

The magnet attracts the metal plate to the ground. The plate restricts the rotation of the bollard; this is how the bollard is in its fully erected position.

4.0 Concept Selection

The selection process is summarized as follows

- Initial Pugh Chart winnowing
- Weighted Decision Matrix
- Final Decision

Initial Pugh Chart Winnowing

Once all the concepts were presented to the group, a pugh chart was implemented to each concept. The concepts were narrowed down to the following four.

- Cable Hook Concept
- Magnet Concept
- Lock Ball Concept
- Shear Pin Concept

Cable Hook

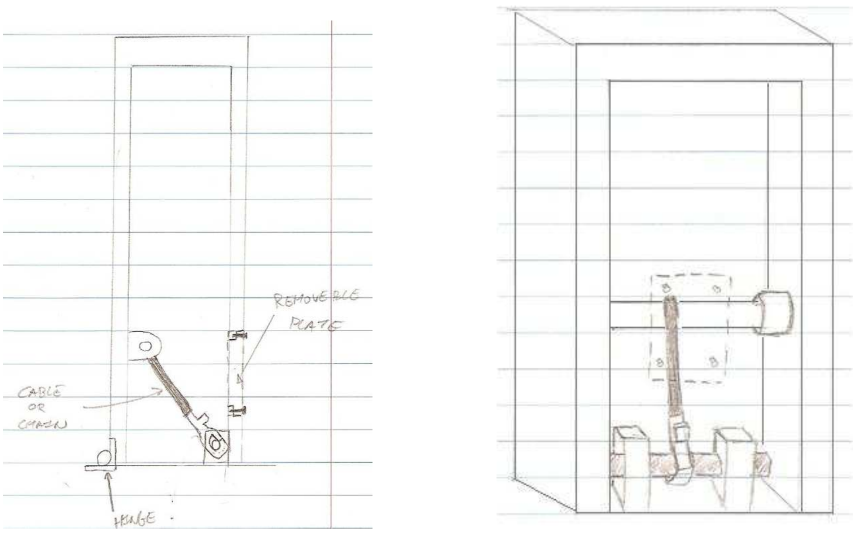

Figure 4.1 - Cable Hook Design

The cable hook design is essentially the combination of the tensioned line and the shear pin concepts. The tensioned line is connected to the shear pin through a carabineer. To manually release the bollard, the removable plate is removed by unscrewing four set screws to gain access through the opening. The quick release carabineer is then unlocked and unhooked from the shear pin. When fully erected and locked in, the shear pin is the load bearing component. The force applied from a vehicle will increase the tension on the line; the carabineer will apply a direct shearing force to the shear pin. The pin will then fracture at a pre-determined stress limit.

Two of the strengths of this design are its simple design and its cheap cost of manufacture. Essentially all this design is a hook pulling on a shear pin. The simplicity of the design significantly decreases the complexity of the analysis on the bollard, compared to the MaxiForce bollard. Also, all the parts for the bollard can be readily found in most hardware catalogs and the casing can be easily machined at any local machine shop, which lowers the cost significantly.

Some of the weaknesses of the design are the long disengagement and re-engagement time of the carabineer and the difficulty of preloading the tension line after it has been released. To be able to get to the tensioned line mechanism, the user must remove the plate that covers the inner workings and then unlock the carabineer by turning the screw lock. The time it takes to do this is a major flaw in the usability of the bollard, compared to the standard Maxiforce bollard. To re-establish the correct tension on the line and have the hook fully engaged with the shear pin will be somewhat difficult without additional personnel or tools. This is a major flaw compared to the standard Maxiforce bollard.

Magnet

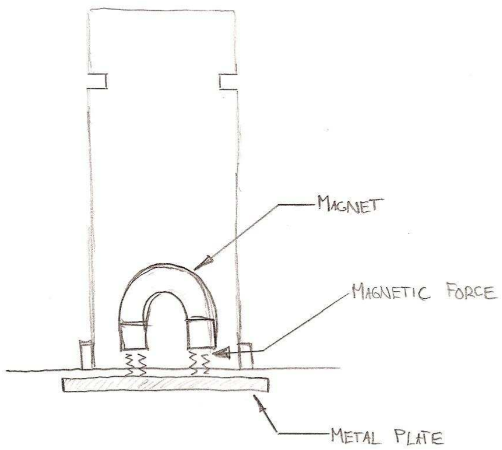

Figure 4.2 - Magnet Concept

The magnet concept is essentially using the attractive force of the magnet as the bracing force. To disengage the magnet, it needs to be either pulled away from the metal plate a small displacement before the bollard is disengaged or have the magnet de-activated depending on the type of magnet used.

Some of the strengths of this design its use of standard parts, small quantity of parts and lack of fracturing components compared to the previous concept.

The magnet and metal plate can be sized and obtained within a short amount of time. The availability of the components would be an advantage to a producer, who possibly would market this bollard and put into service with very little lay over time. This self sustained bollard has no fracturing parts, this in a sustainable perspective is a viable choice because it reduces the dependency on resources to operate and maintain the bollard.

The weaknesses of this design are the uncertain disengagement method and the durability of the magnet. One of the only ways to disengage the magnet is to increase the distance between the metal plate and the magnet. There are however lifting magnets which do not require a power source that can be switched on or off which may be incorporated into the design.

Comment [RS4]: someone want to finish this point…not sure wut to put

All magnetic materials have dissipative magnetic abilities over time. The strength of the magnet will not be exactly the same as the day it was installed. Without a power source or re-magnetizing coil, the magnet within the bollard would need to be replaced eventually; so consistent surveillance of the performance of the magnet needs to be done.

Lock Ball

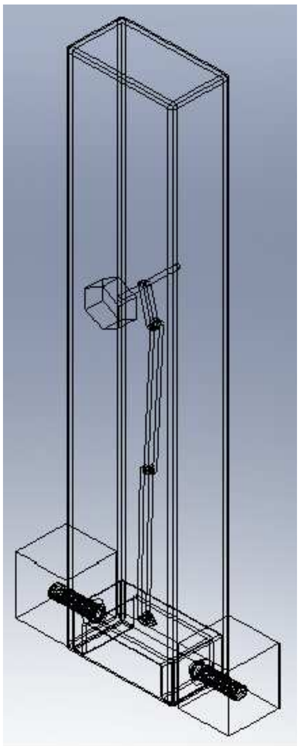

Figure 4.3 - Lock Ball Concept

The lock ball concept uses the friction load barring and linkage concepts. When the user turns the fire hydrant nut, it lifts the set of linkages that are connected directly to the load barring mechanism. As seen in figure 12, the springs on each side of the bollard apply a force to each hammer. This force pinches the block on both sides. The frictional force generated is used to bare the load of a car collision.

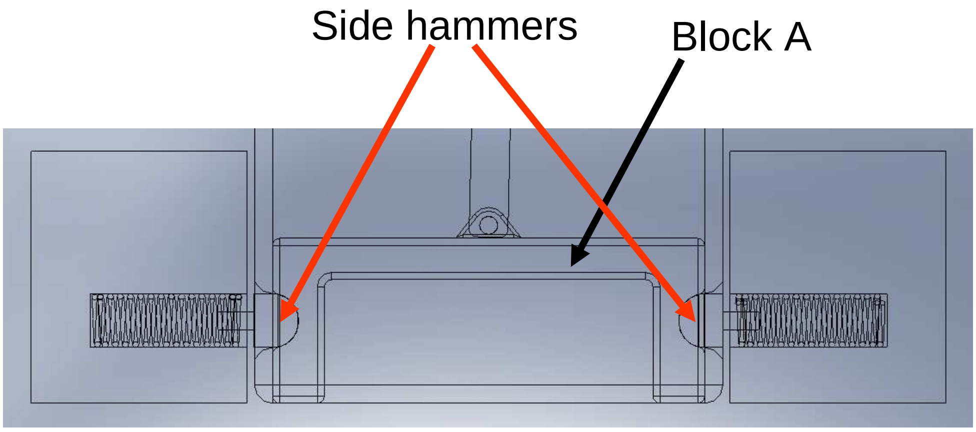

Figure 4.4 - Lock ball engaged

As the linkages are lifted from the rotation of the nut, it raises the block. The block applies reaction forces onto each hammer; this will cause the hammers to be pushed back into the springs. The bollard is now able to be collapsed when the side hammers are not pinching on the block as seen in figure 4.5.

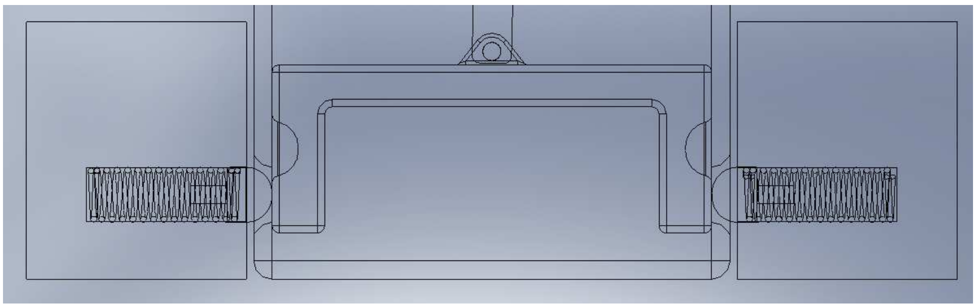

Figure 4.5 - Lock ball disengaged

The benefits of this design are simplicity of the locking mechanism and operation with no broken parts.

The main disadvantage of this design is the engagement and disengagement of the bollard after it has been collapsed. The approximate force that a car collision applies is in the range of 700 lbs of force. The frictional force is the main component of barring the load. For typical maintenance personnel to push the bollard hard enough so that the side hammers will be pushed back into the sides, will require a large physical effort. The usability of the design can be questioned because of this.

Shear Pin

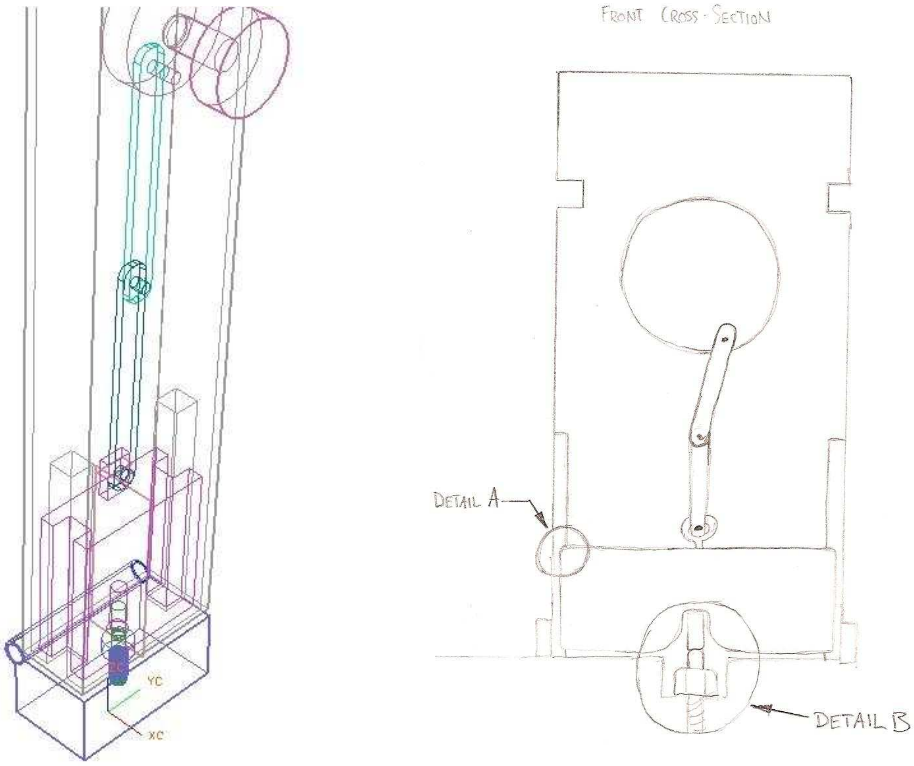

Figure 4.6 - Shear Pin

The shear pin design involves linkages and a grooved, threaded shear pin. The shear block that covers the shear pin, is initially fixed to the overall motion of the bollard. When the fire hydrant nut is turned, the block is raised high enough, so there is no load barring component engaged; then the bollard can be freely collapsed. If the block is left in its engaged position, the shear pin will take the car collision load that is transmitted through the block.

The advantages of this design are quick replacement of the shear pin after being collapsed, fast manual disengagement and simple manufacturing processes. The pin is specially designed so that after the bollard is collapsed, there is a small nut that can be accessed by a socket wrench. The accessibility of the socket wrench makes it quick and easy, to replace the pin. Fast disengagement is achieved by the linkage system, once the block lifted; it is just a matter of pushing the bollard. The machining processes required are fairly simple because there are no complex geometric components within the bollard. The processes can be done fairly fast by a machinist or a CNC machine.

The main disadvantage of this system is the fracturing of shear pins because of the dependence of raw materials for more shear pins.

Weighted Decision Matrix

The previous concepts are put judged against a weighted decision matrix. Each criteria is describe as follows.

Criteria	Weight %	Cable Hook		Magnet		Lock Ball		Shear Pin	
		Raw	Adj.	Raw	Adj.	Raw	Adj.	Raw	Adj.
Sunk Cost	25	9	22.5			6	15	8	20
Variable Cost	15	5	7.5			7.5	11.25	7	10.5
Setup/ Disengage Time	15	2	3			7	10.5	7	10.5
Durability	5	4	2			4.5	2.25	7	3.5
Ease of use	15	5.5	8.25			7	10.5	8	12
Effectiveness	15	7.5	11.25			**5**	7.5	8.5	12.75
Safety	10	7	7			5	5	8	8
Net Score	100		61.5				62		77.25

Table 1: Weighted Decision Matrix

Comment [RS5]: replaced spring force with magenet…I think the scores would be different…discuss 2morrow?

5.0 Concept Validation

Each of the concepts reviewed in the previous section fulfills the functional requirements outlined earlier in this report. This section of the report will check each of the candidates to see how each design reflects our evaluation criteria and how they reflect the client's desires. The evaluation criterion is composed of the following categories:

- Sunk Cost (Manufacturing/Raw Materials)
- Variable Maintenance Cost (Lifecycle Costs)

- Setup/Disengagement Time
- Durability
- Effectiveness (Force required to break away)
- Ease of Use
- Safety

The purpose of having costs divided into two different categories was to differentiate between the initial manufacturing cost and the long term life cycle costs. It can be assumed for the application of a bollard on the UBC campus it would take approximately 10 minutes to travel to the bollard and 10 minutes to travel back to the sustainability office for operators doing maintenance work on a bollard. Any amount of time required to setup or disengage a bollard would thus have to add 20 minutes to factor in travel times, which is amount in wages that would have to be paid. So a difference in one minute compared to five minutes in disengagement time would equate to an overall total time spent of 21 minutes and 25 minutes. The difference of 4 minutes in labour wages would be the difference in cost savings in this case.

Cable Hook Concept

The Cable Hook concept is a very simple design with few internal components that performs the functions required by the project. This concept is the simplest to manufacture of the four concepts and also the cheapest to manufacture. Although this design does meet the functional requirements it lacks greatly in its disengagement/setup time thus increasing its variable maintenance costs. It is estimated that this design would take approximately five minutes to go through the procedure of disengaging or re-engaging the bollard. This fault is too great and will not be considered as a final design the Shear Pin concept functions similarly with the shear pin except it has a much faster disengagement mechanism.

If there were a way in which the cable could be re-attached to the shear pin externally with a fire hydrant wrench then this concept could be viable but the inconvenience of its use for the operator and the extra time spent is not worth the sunk cost savings.

Magnet Concept

The Magnet concept relies on a permanent magnet for both the manual disengagement mechanism and vehicle impact break away mechanism. There are no parts broken with this concept as the breakaway mechanism involves overcoming a magnetic force. A special type of magnet would be used which can have its attractive forced enabled or disabled by a switch.

Figure 5.1 – Lifting Magnet

The magnet illustrated in the figure is an example of the type magnet that will likely be used in this design, although the type of handle and user interface is not fully developed.

The validity of this concept is proved however, as these magnets can range anywhere from 100 lbs all the way to 10,000 lbs of attractive forces. A model would be chosen based on the breaking force required. No electricity is required and manual disengagement/re-engagement would be very simple. An operator turning the switch would be able to disable the magnet, allowing the bollard to be knocked over. The breakaway mechanism would simply be a vehicle striking the bollard to overcome the attractive force between the magnet and the base of the bollard.

The interface between the exterior operator's tool and the switch of the magnet has yet to be determined. The large advantage here is that setup and for all methods of disengaging and breaking away would be quick and no parts would be broken. The estimated time to re-engage and disengage the bollard would be a matter of seconds, with no additional time effort added in setting up the bollard by having a vehicle impact. The magnets however would add a sunk cost of approximately $200 per magnet. Additionally, all powerful magnets have adverse affects to nearby electronics, and although the chance is very small, it could be an inconvenience or even a hazard if a pedestrian with a pace maker were too close.

Something to improve upon for this design would be to determine the exact mechanism upon how a fire hydrant wrench from the exterior could activate or deactivate the magnet within the interior of the bollard. If this is ironed out this design could be a very competitive and sustainable design.

Lock Ball Concept

The Lock Ball Spring concept is another design in which no pieces are broken for the breakaway mechanism, which is great from a sustainability perspective. This product would require more physical effort to manually disengage and re-engage the bollard, but could potentially be performed at the same speed as the Maxiforce bollard if a mechanical advantage exists in transferring the force from an operator's fire hydrant wrench.

One caution of this design is to validate whether an operator could apply enough force to manually disengage the bollard. Some preliminary calculations were performed and free body diagrams were drawn with different shaped contact surfaces for the side hammers of the lock ball concept. It was determined that a bowl shaped curved contact would be ideal in for this design as breaking away from the cavity would be more difficult than to re-enter the cavity with this shape. In terms of sunk costs they would likely be similar to those of the shear pin, and once again if a method that required less physical effort were refined this concept would be very competitive as there would be very few drawbacks to this design relative to the maxiforce.

Shear Pin

The shear pin concept is a very low risk design with few uncertainties and very easy to perform studies on. It functions very similarly to the maxiforce design. All of the evaluation criteria are met in this design without uncertainties, and the only disadvantage of a shear pin breaking may be negated due to several reasons. For one, the shear pin only breaks upon vehicle impact. Frequency of vehicle impact is likely much lower than frequency of manual disengagement of a bollard, so importance of speed for manually disengaging and re-engaging will carry more weight. The second point is that the material cost of a shearing pin is so low that the replacement cost would be almost negligible compared to the labour costs associated with replacing a broken shearing pin. Due to this, any method of minimizing the time spent re-setting a bollard from vehicle impact which this concept does quite well and possibly faster than the maxiforce design. The Lock Ball concept and the Magnet concept would be faster in this respect however.

6.0 Conclusions and Recommendations

There is not yet a single conclusive design at this stage in development, as there are still several disadvantages that for each design concept that could possibly be further refined and removed with further detailed development. At this point there are still three concepts that are promising. One of the designs, the Shear Pin concept, is a lower risk concept with few uncertainties and will be simple to analyze. The other two concepts, the Lock Ball and Magnet, are both potentially higher performing but riskier designs with more difficult analysis involved.

The advantage to the Lock Ball and the Magnet concepts were that there are no broken pieces upon vehicle impact with a shorter re-engagement time although this method as no shear pin is to be replaced. The major disadvantage to the Lock Ball concept is that it may require too much physical effort to manually disengage the bollard by fire hydrant wrench as a great amount of force would be required to move the hammers out of their cavities. The major disadvantages to the Magnet concept are the increased sunk cost and the unrefined design of the external control of the magnet control switch. If either of these processes were refined further then these ideas could be safe enough to replace the shear pin concept.

The shear pin concept however is not too far behind in performance. If it is determined that bollards are infrequently struck by vehicles and are far more frequently manually disengaged/re-engaged by fire hydrant wrench, then not enough pins may be broken to justify the extra costs of the magnet concept or the strength-reliant lock ball concept. So in the end it could turn out that any of these three concepts could be chosen for the final design.

Each concept shall be refined in a different way: The shear pin concept will likely be focused on making the design simpler and cheaper to produce. More analysis will have to be performed on the Lock Ball concept to verify if the force required is within a comfortable physical range. We may have to look at different types of interfaces for lifting magnets or contact manufacturers to see if there are different types of magnets more appropriate for our application for a simpler design. From here additional analysis including FEA and fatigue analysis will be required for further insight. In the end a meeting with the clients, Brenda, Kelly, and Mike may be required to see if there is a concept which is favoured by the three of them. If all three concepts are refined to the point where they function equally, cost may be the ultimate deciding factor.

7.0 References and Appendices

Figure 1.1

ATG Acess - Products

http://www.atgaccess.com/products/ATGLiverpoolBollards6.bmp

SHEARSOLUTIONS

Mech 457

Collapsible Bollard Technical Analysis

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John Chang
Richard Situ

Date Submitted: December 19, 2008
Word Count: 3943

Abstract

The purpose of this technical analysis was to determine the feasibility of the lockball concept previously outlined in the conceptual alternatives report. The lockball bollard concept uses spherically shaped lockballs which are pinched into specially shaped cavities by spring forces to retain the bollard in an erect position. This analysis studies the level of impact forces required to overcome the pinching forces of the lockball in the cavity. It is determined that the shape of the cavity and the strength of the springs influence the level of impact force required before disengaging the bollard. An FEA analysis is performed, concluding that the lockball component would be the first to shear if failure were to occur. The basic geometric layout is also included in this document.

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1.0 Introduction

The purpose of this project is to design a collapsible bollard that will meet the requirements outlined in the project proposal document. The key functional requirements were described as the following:

- Prevent or limit access to unauthorized vehicles
- Allow emergency vehicles access
- Manual disengagement mechanism for a worker

In addition to these functional requirements other factors of consideration were the initial and operating costs, ease of use, material replacement (due to impact), safety, and ease of use of the bollard. After consideration of these different aspects the Lock Ball Bollard Concept was chosen as the pursued design. The Magnet concept was another contender which was believed to be unsafe due to magnets not being designed for impact and being very brittle leading to the possibility of shatter upon vehicle impact. Another disadvantage of the magnet concept was its substantially higher initial costs of approximate $250 per magnet as well as the costs for an additional safety precaution to deter the effects of the magnetic field, which made the design too complex. These costs did not offset the savings that would be made in set up time when compared to the Lock Ball design.

Figure 1.1 illustrates the release mechanism for the Lock Ball design. As seen figure 1.1, a spring force is applied horizontally to force the side lockballs within the bowl shaped cavity. The cavities are part of the bollard base while the hammers are firmly connected to the shell of the bollard. When the is turned by a fire hydrant wrench, the linkages pull the springs horizontally inwards, allowing the bollard to be collapsed as the side hammers are no longer pinching into the cavities. The pinching force of the side hammers due to the springs is what must be overcome by a vehicle to disengage the bollard by impact. A mechanical advantage is created through the shape of the cavity and creates different angles for normal forces.

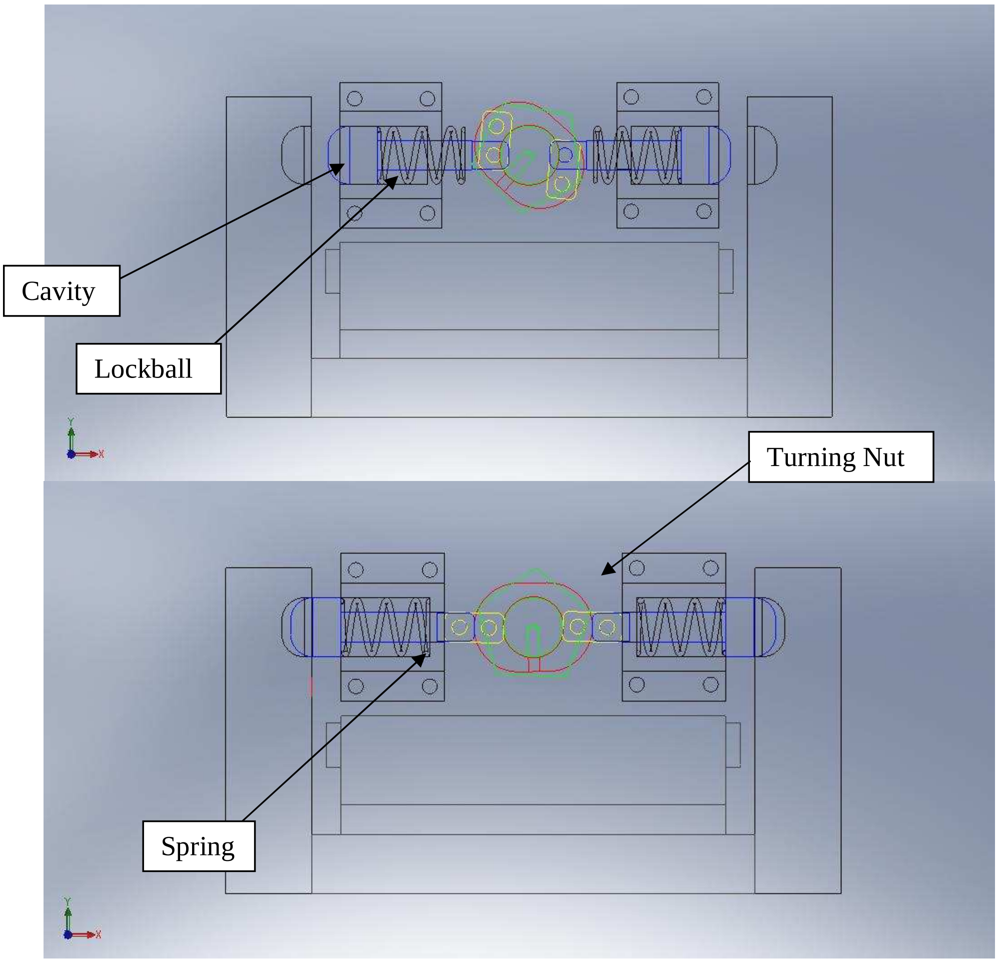

Figure 1.1 – Disengaged and Engaged Positions of Lockball

The conceptual alternatives report outlined many of the key advantages and disadvantages of this design. One of the key advantages to this design is that it is unique relative to existing bollards in the industry. Other designs rely on a pin to shear upon vehicle impact, whereas in this design the lock ball simply pops out of a cavity, resulting no broken partss. Ideally it should be just as quick as the currently used Maxiforce collapsible bollard when manually disengaging and re-engaging. This is where the greatest frequency of user interaction is expected.

Another issue is the strength of the chosen springs is limited to what is comfortable for a user to compress through turning the fire hydrant nut. A mechanical advantage will be required through the shape of the balls and cavity in order to amplify the resistive impact force to a significant enough level to deter vehicle impact. In this report, further analysis of these issues will be completed using Finite Element Analysis (FEA), hand calculations, and Failure Modes and Effects Analysis (FMEA). Basic geometries and classification of standard parts and subassemblies are listed in the following section.

2.0 Product Architecture and Configuration Design

2.1 Schematic and Elements of the Bollard

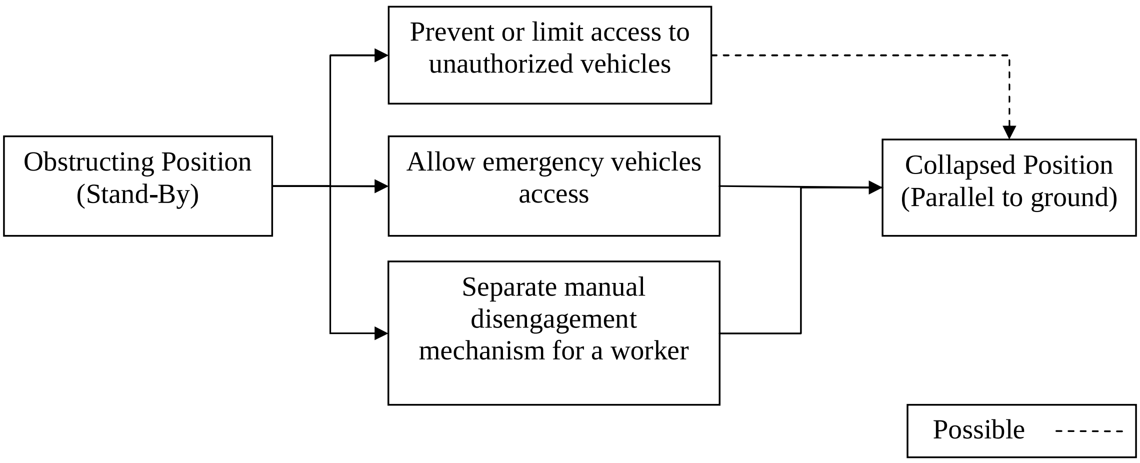

Figure 2.1

The functional elements of the bollard which have not yet been reduced to physical components are shown in figure 2.1. These elements are important to the bollard concept and reflect the basic functional requirements needed for the bollard. All schematic drawings are attached in the Appendix A.

2.2 Geometric Layout of the Bollard

Special Purpose Parts

Below are the general dimensions of the manufactured sub-assemblies which composed the overall bollard assembly

2.2.1 1x Bollard Shell

Refer to Figure 2.2

Dimensions: Refer to drawings in Appendix A.

Made of 1/8” thick Steel. The Bollard Shell is fabricated by bending steel plating and welded together. The shells purpose is to deter vehicles and contain the disengagement mechanism. Hinge pivots are located on Bollard Base (Figure 2.3)

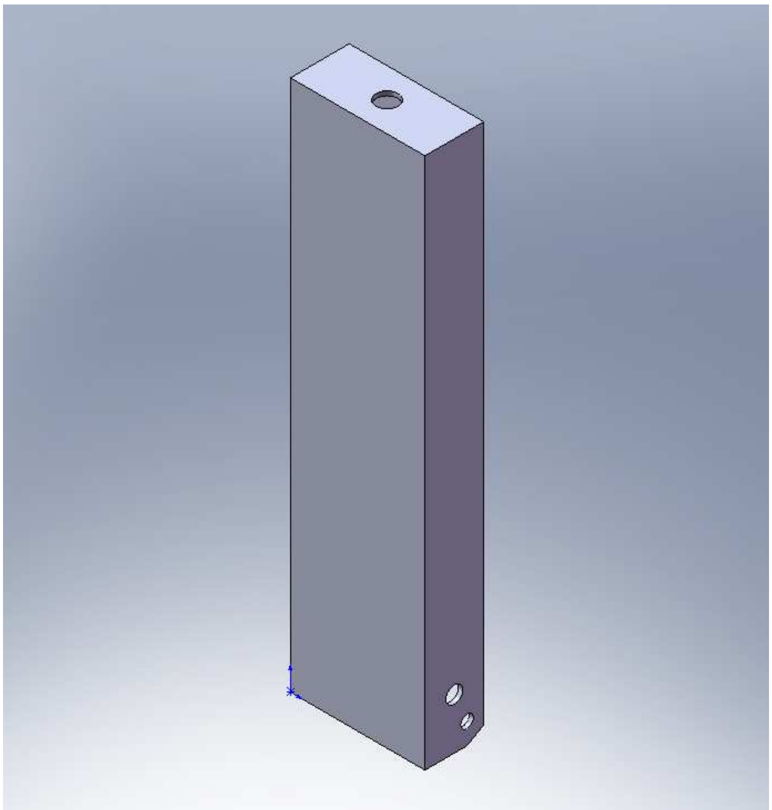

Figure 2.2 Bollard Shell

2.2.2 1x Bollard Base

Refer to Figure 2.3

Dimensions: Refer to drawings in Appendix A.

Custom made steel block. Hinge mechanism is included. Cavity Bases (Figure 2.4) are attached on Bollard Base.

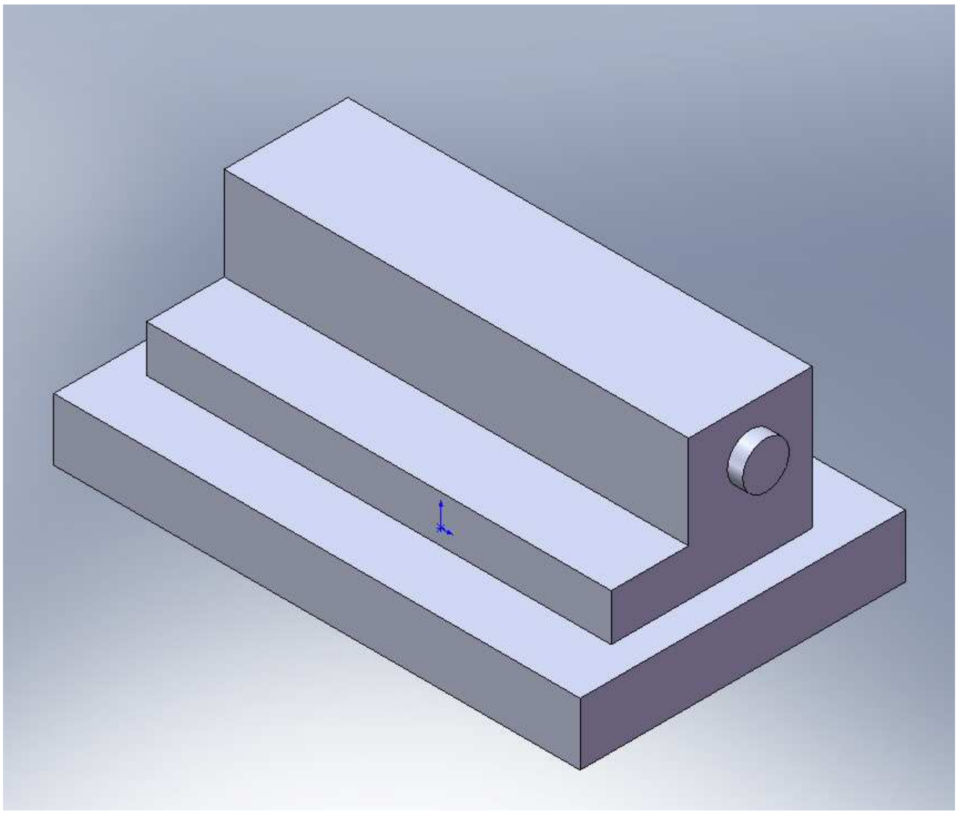

Figure 2.3 – Bollard Base

2.2.3 2x Cavity Base

Refer to Figure 2.4

Dimensions: Refer to drawings in Appendix A.

Solid Steel block with custom machined spherical cavity. Lock ball (Figure 2.5) interacts with cavity surface. Welded to Bollard Base (Figure 2.3).

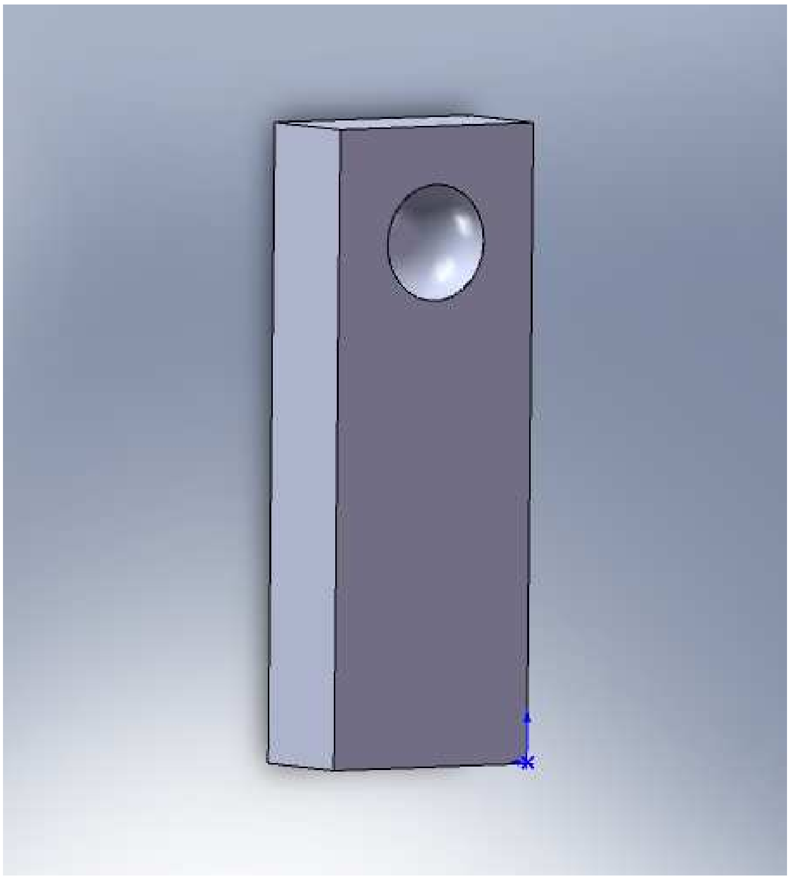

Figure 2.4 – Cavity Base

2.2.4 2x Lock Ball

Refer to Figure 2.5 and Figure 2.6

Dimensions: Refer to drawings in Appendix A.

Lock ball shape is lathed from cylindrical steel material. This surface Interacts with Cavity Base (Figure 2.4). Steel material is lathed thinner passed the lock ball surface and is milled at the end where this section connects to Linkage (Figure 2.7) by bolt and nut to guide the springs.

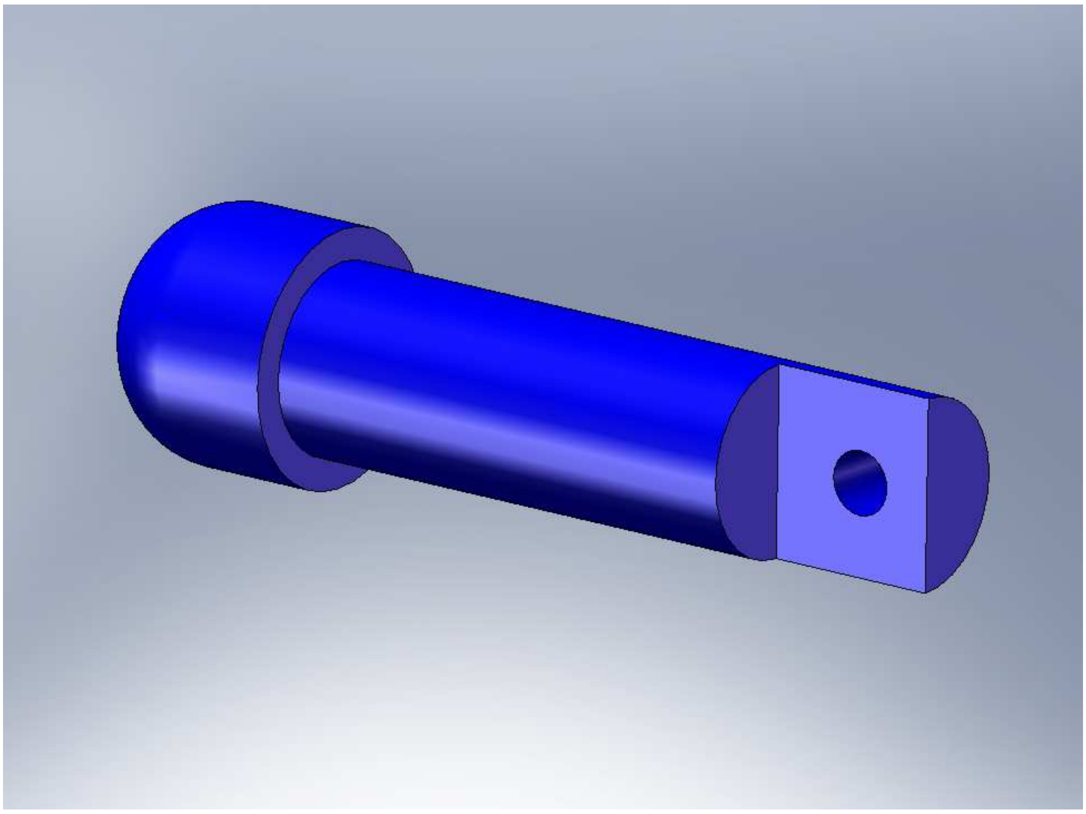

Figure 2.5 – Lock Ball Unit 1

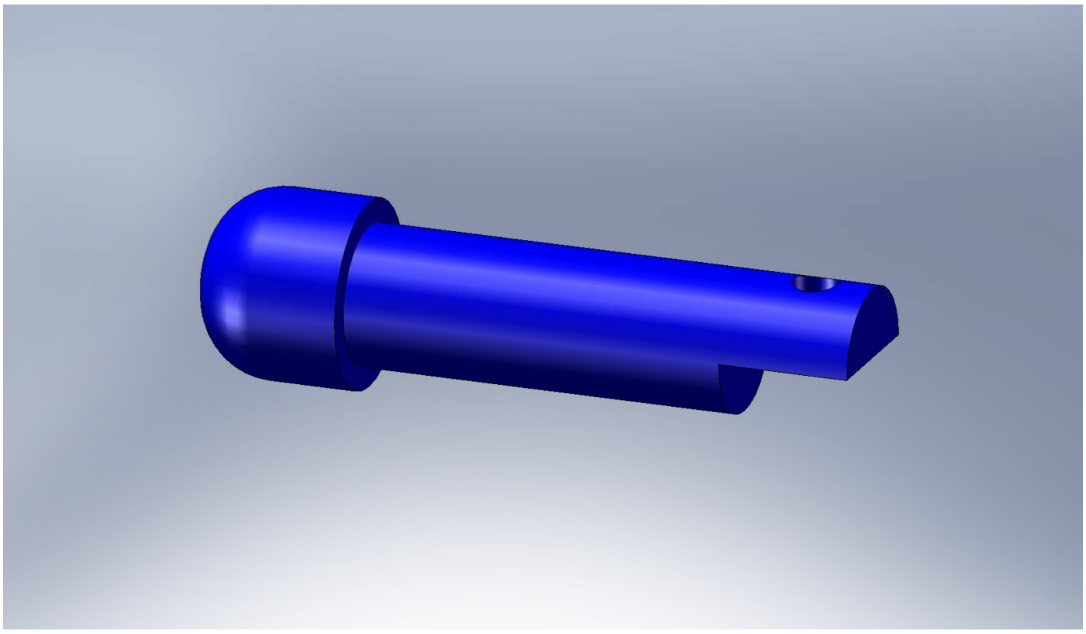

Figure 2.6 – Lock Ball Unit 2

2.2.5 2x Linkage (Yellow)

Refer to Figure 2.7

Dimensions: Refer to drawings in Appendix A.

Linkage connects to Linkage Base (Figure 2.9) and Cylindrical Stock with Flat end and Hole (Figure 2.6) using bolts. The bar linkages transfer the Hydrant Nut rotational motion to the Lock Ball Assembly (Figure B.1) through linear motion.

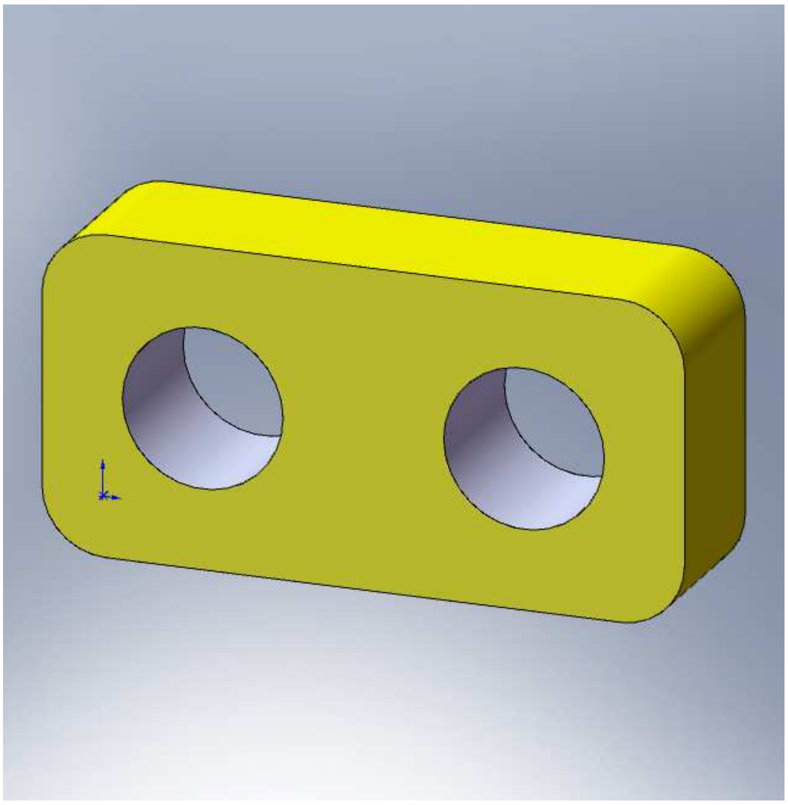

Figure 2.7 - Linkage

2.2.6 2x Spring Support brackets

Refer to Figure 2.8

Dimensions: Refer to drawings in Appendix A.

Steel or Aluminum machined block. This block mounts onto the Shell (Figure 2.2) using Bolts and Nuts. This part guides and supports the Lock ball Assembly (Figure 2.11)

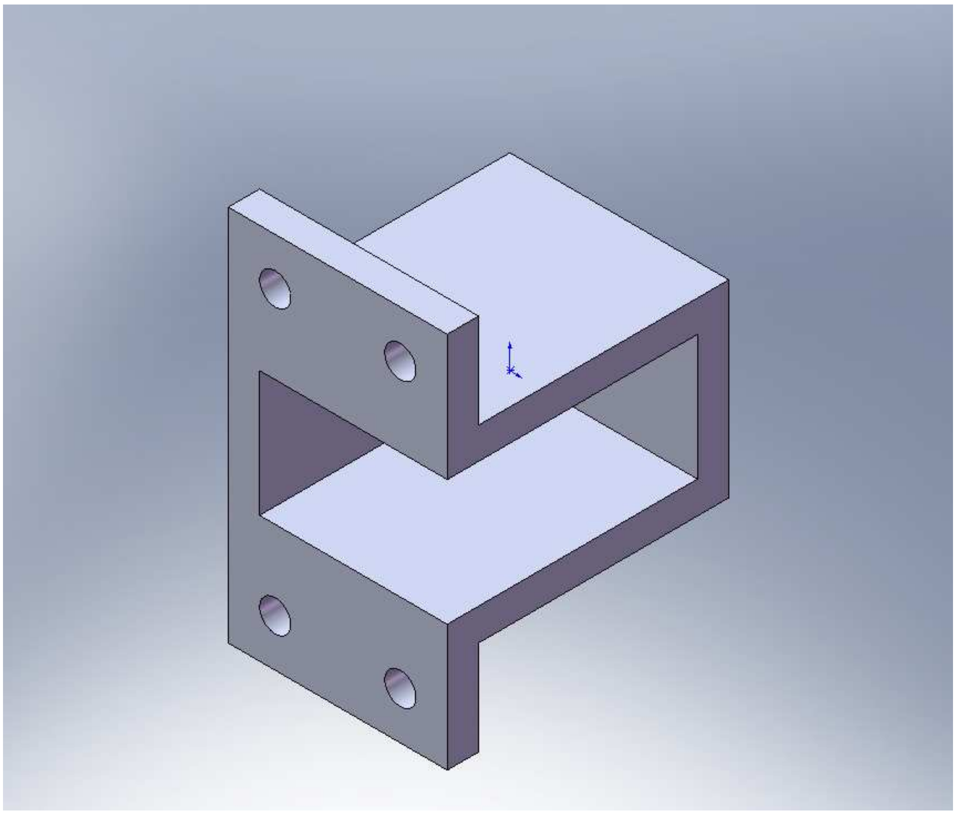

Figure 2.8 – Spring Support Bracket

2.2.7 1x Linkage Base

Refer to Figure 2.9

Dimensions: Refer to drawings in Appendix A.

Steel or Aluminum custom machined block. Mounts Linkages (Figure 2.7) and Special Hydrant Nut (Figure 2.10)

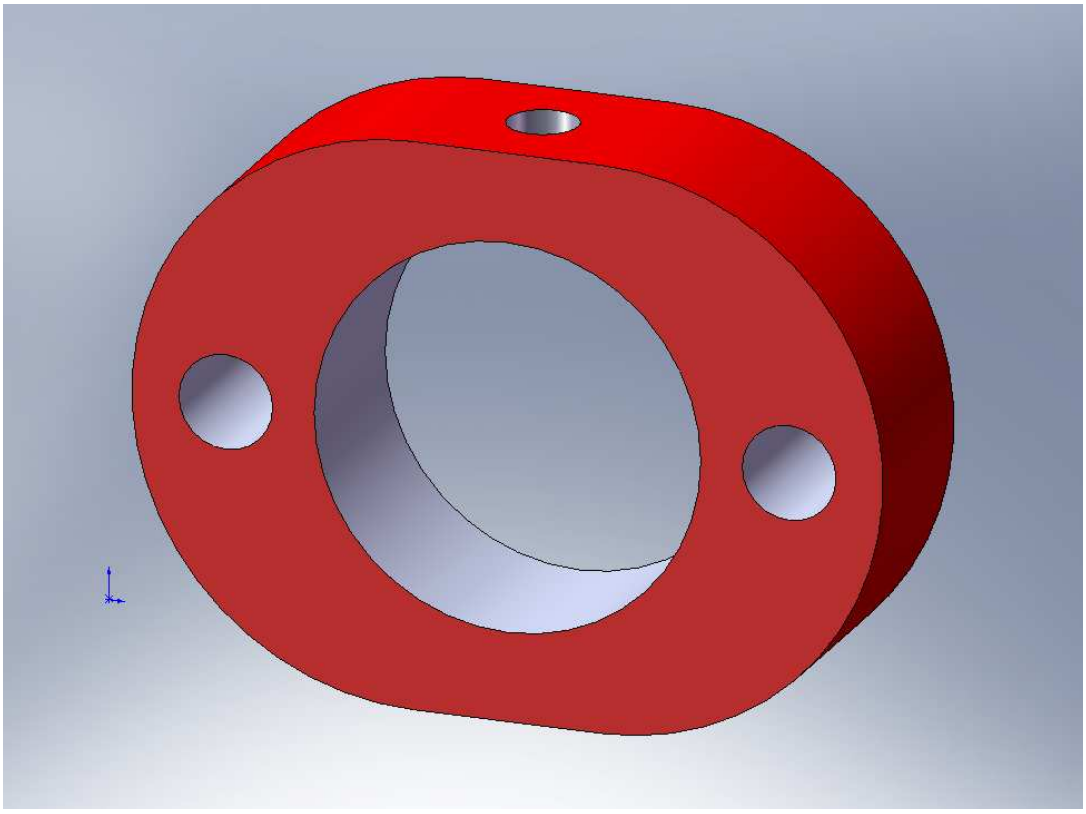

Figure 2.9 – Linkage Base

2.2.8 1x Hydrant Nut with cylindrical stock

Refer to Figure 2.10

Dimensions: Refer to drawings in Appendix A.

Steel machined cylindrical stock welded to standard hydrant nut. This piece is mounted on to the Linkage Base (Figure 2.9) using a Bolt. A fire hydrant wrench turns the nut, which rotates the Linkage Base.

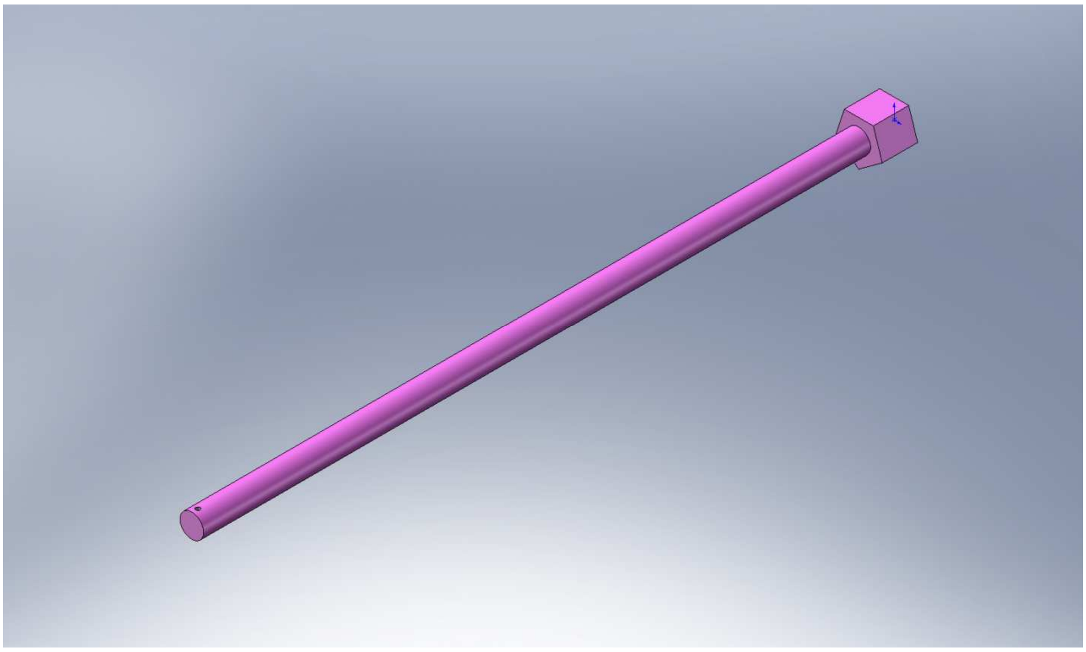

Figure 2.10 – Hydrant Nut with cylindrical stock

2.3 Assemblies and Sub-assemblies

2.3.1 Lock Ball Assembly

Refer to Figure 2.11

This assembly contains Lock ball (Figure 2.5), Cylindrical Stock with Flat end and Hole (Figure 2.6) and a spring. It will be positioned in the Spring Supporting Brackets (Figure 2.8) connected to the Disengagement Mechanism Assembly (B.2)

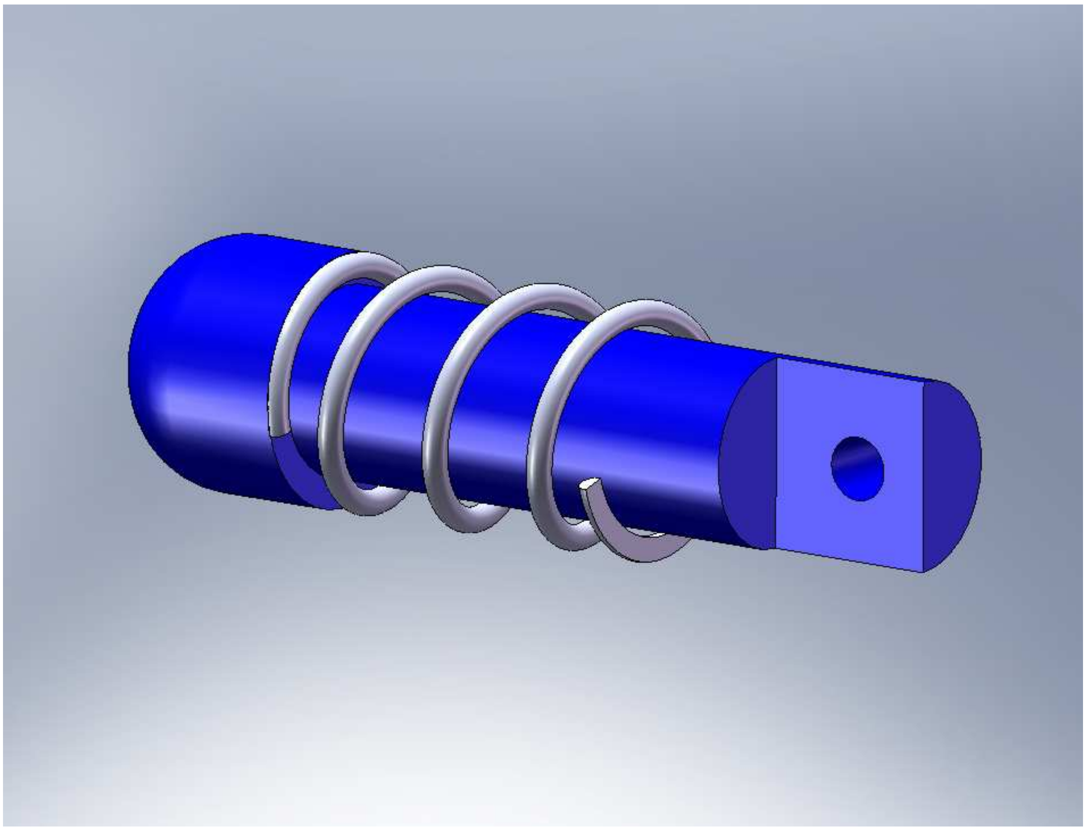

Figure 2.11 – Lock Ball Assembly

2.3.2 Disengagement Mechanism Assembly

Refer to Figure 2.12 and Figure 2.13 for engage and disengage mode.

The engagement mode is when the lock balls are in the cavity bases, keeping the bollard upright and ready to receive impact from a vehicle. The disengagement mode is when the lock balls are out of the cavities thus unrestricting the bollard from falling to the ground.

This assembly contains two Lock Ball Assemblies (Figure 2.11), two Cavity Base (Figure 2.4), two Linkages (Figure 2.7), two Linkage Bases (Figure 2.9) and one Special Hydrant Nut (Figure

2.10). By turning the Special Hydrant Nut, the Linkage Base rotates and pulls in the Lock Ball Assembly. Since the springs are pushing against the Supporting Brackets (Figure 2.8) the spring force will keep the Lock Balls within the Cavity Base. The normal force of the cavity imparted upon the lock balls will have to be overcome in order to disengage the bollard upon impact.

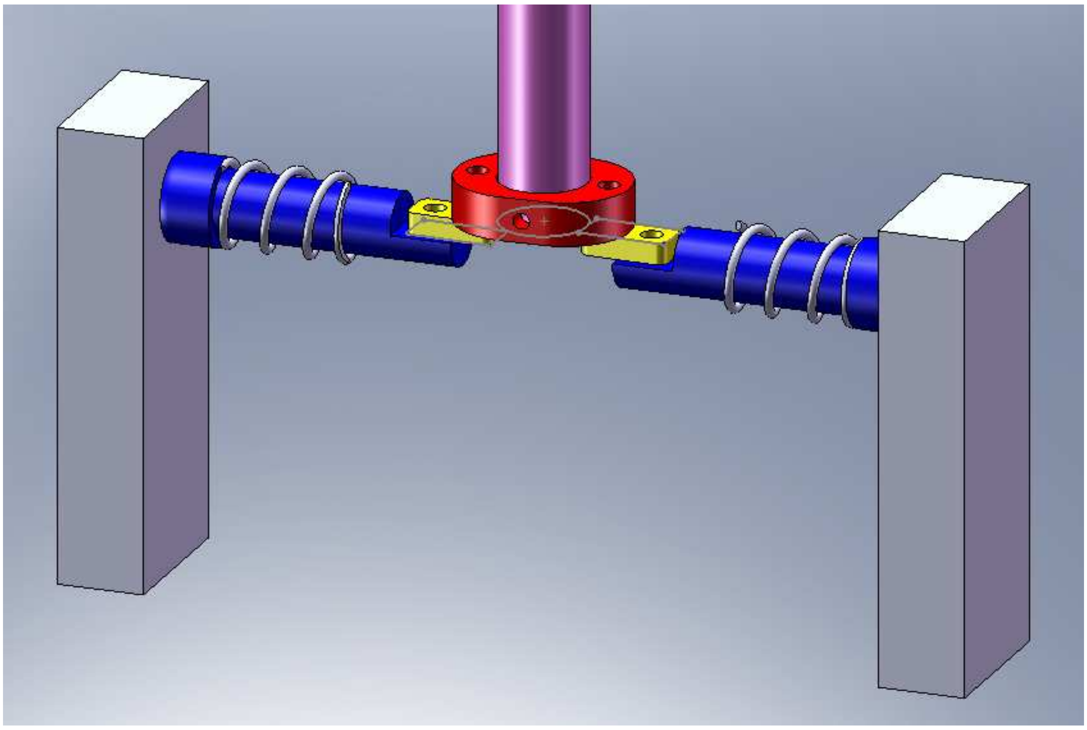

Figure 2.12 – Disengagement Mechanism Engaged Position

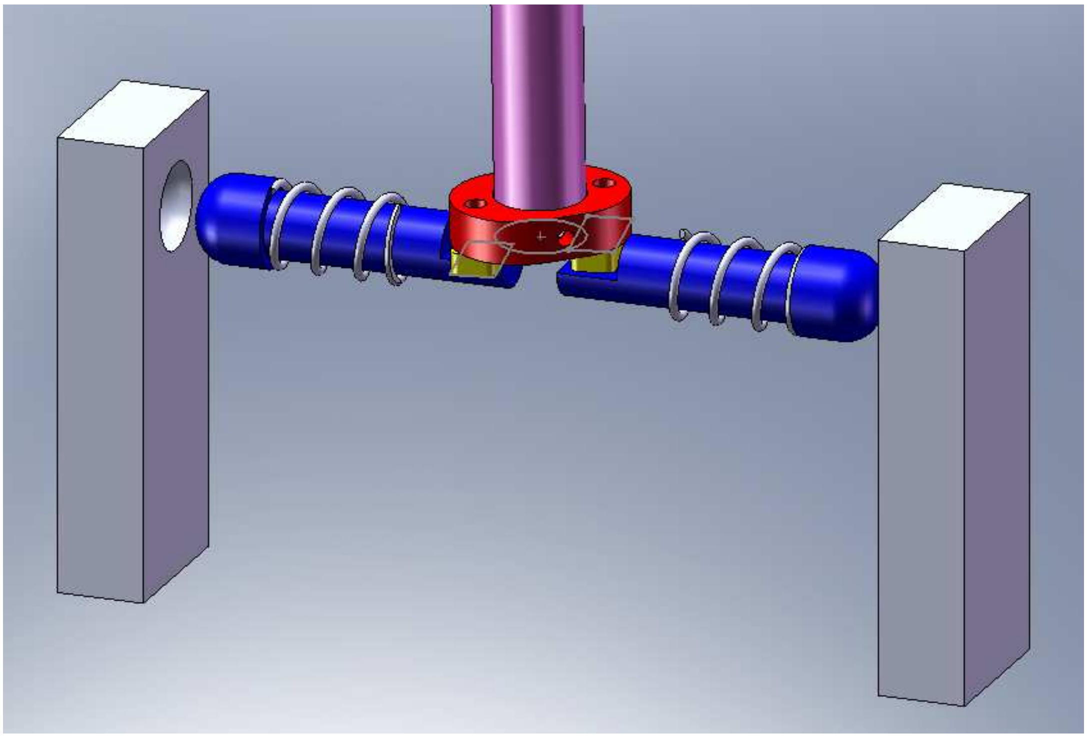

Figure 2.13 – Disengagement Mechanism Disengaged Position

2.3.3 Mounting Base Assembly

Refer to Figure 2.14 and 2.15.

This assembly contains the Bollard Shell (Figure 2.2), Bollard Base (Figure 2.3), 2X Cavity Bases (Figure 2.4) and 2X Spring Supporting Brackets (Figure 2.8). The Bollard Shell is mounted onto the Bollard Base by a custom hinge, where it pivots on. The Spring Supporting Brackets are mounted on the Bollard Shell using Bolts. The Cavity Bases are welded to the Bollard Base.

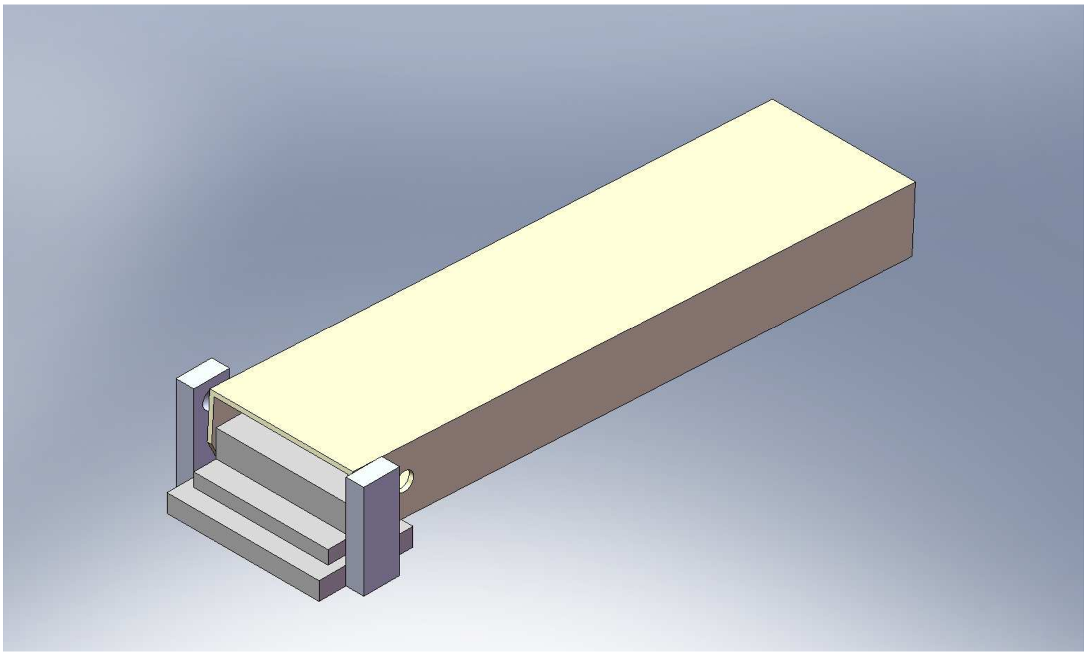

Figure 2.14 – Mounting Base Assembly

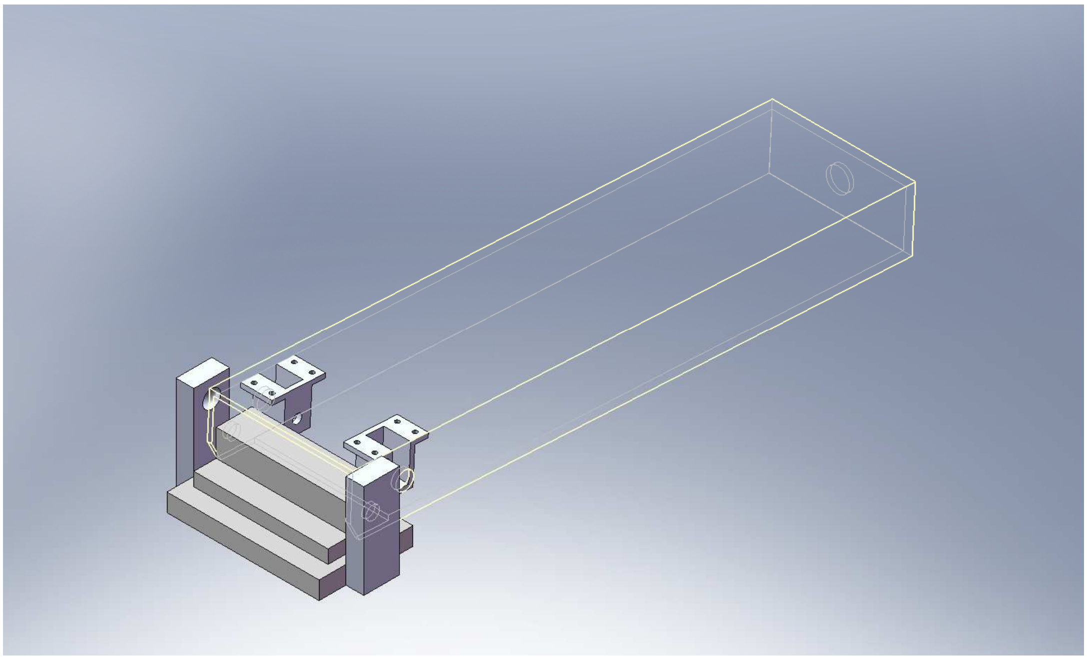

Figure 2.15 – Mounting Base Assembly

A. Standard Assembly

None (motor, gearboxes, pumps)

B. Final Assembly

Refer to Figure 2.16 and 2.17.

This assembly contains the all the Mounting Base Assembly and the Disengagement Mechanism Assembly. This is the complete assembly of the Collapsible Bollard.

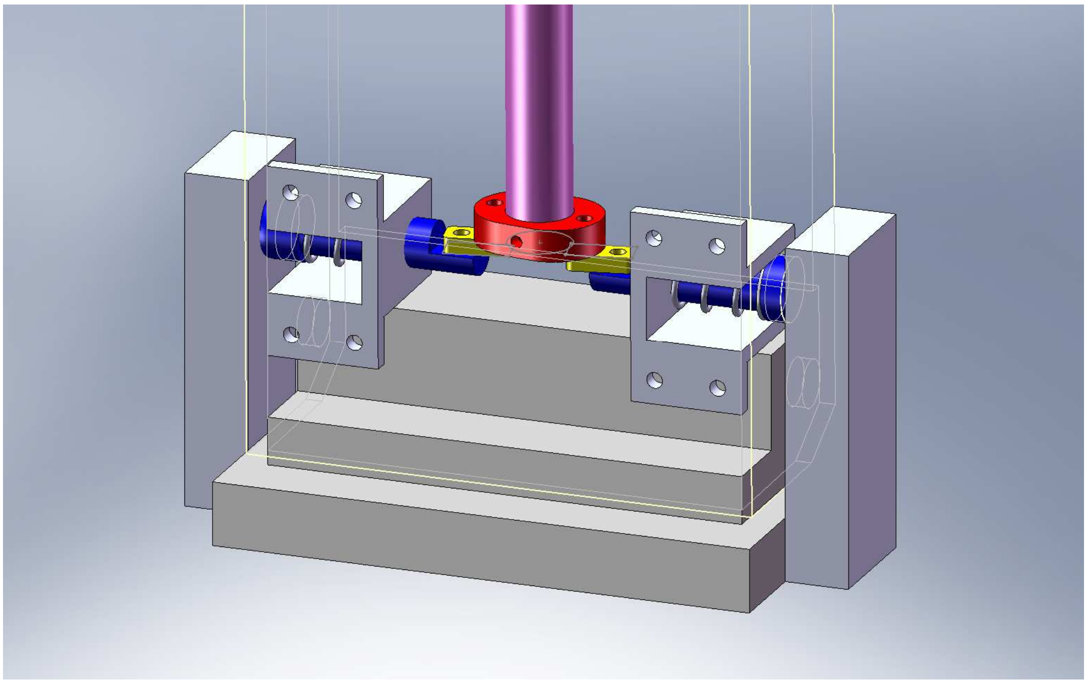

Figure 2.16

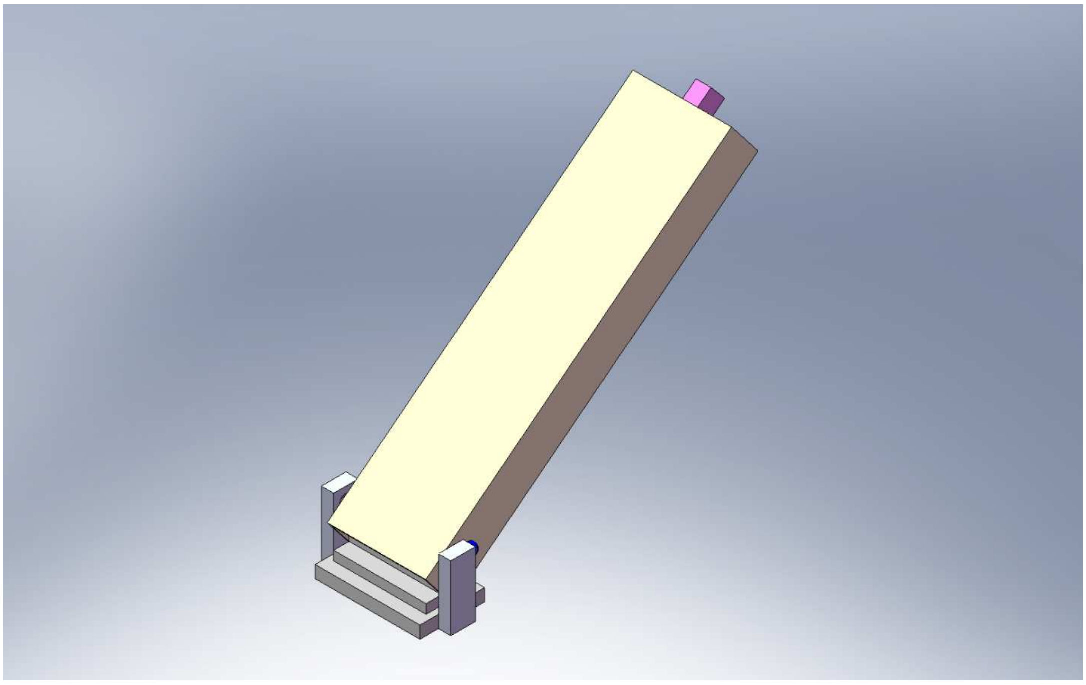

Figure 2.17

Standard Parts

The following is a listing for all the standard parts used in the Collapsible Bollard design.

Bolts

Part	Quantity #	Thread Diameter	Min. Length	Purpose
a	8	3/16”	3/4”	For mounting Spring Support Bracket (Figure 2.8) onto Bollard Shell (Figure 2.2)
b	1	1/8 “	3/4”	For mounting Special Hydrant Nut (Figure 2.10) to Linkage Base (Figure 2.9)
c	2	3/16”	3/4”	For connecting Linkage (Figure 2.7) to Cylindrical Stock with Flat end and Hole (Figure 2.6)
d	2	3/16”	3/4”	For connecting Linkage (Figure 2.7) to Linkage Base (Figure 2.9)

Nuts

Part	Quantity #	Thread Diameter	Purpose
e	12	3/16”	Nuts used at the Bolt ends

Washers

Part	Quantity #	Min. Inner Hole Diameter	Purpose
f	12	3/16”	Flat Washers used for Bolts

Springs

Part	Quantity #	Uncompressed Length	Purpose
g	2	1.5”	Compression Box End Grounded springs used to generate repulsive linear force so the Lock ball Unit (Figure 2.5) stays in Cavity Base (Figure 2.4)

3.0 Parametric Design

The most important parameter to analyze is the feasibility of the lock ball spring mechanism. The spring strength should be chosen such that an operator can comfortably turn the nut on the bollard by fire hydrant wrench to compress the springs. However, a mechanical advantage should be provided from the shape of the lock ball and cavity due to the normal forces they provide through contact. Concerning the feasibility and effectiveness of the design, a detailed analysis on the spherically shaped lock balls and cavity force interactions must be performed. The actual size of the cavity and lock ball would affect the amount of contact area between the two pieces as well as the strength of the pieces themselves in case of failure before disengagement of the bollard.

In this section, an FEA analysis is performed on various parts of the bollard for the breaking strength of a load that would be applied due to a vehicle colliding with the bollard and arriving to a complete stop without the lock ball slipping out of the cavity. The analysis of interaction between the cavity and lock ball shapes could not be completed in a thorough FEA (Finite Element Analysis) analysis through ANSYS© software due to complexity and time constraints, however basic hand calculations with assumptions were made.

This section is concluded by an FMEA (Failure Modes and Effects Analysis) to identify potential failure modes with the design.

3.1 Models and Simulations

3.1.1 FEA Analysis

Analysis was performed on the bollard design using software called COSMOSXpress. The situation is simplified from what would actually happen upon vehicle impact. It is assumed this situation is for a vertical walled cavity, with a car exerting a force of approximately 31250 N statically loaded, located 0.5m above the ground, through the center of gravity of the bollard; using a simplified moment balance, with AISI 1020 carbon steel used for all components. See Figure 3.1 for the moment balance calculation. From our model, it is also assumed that the resultant force acting upon the load barring assembly is located approximately 0.08m from the ground. This is the force required to bring a typical small car to a complete stop which would be the worst case scenario if the lock ball did not pop out of the cavity. This analysis shows the deflection and stress distributions of the various parts of the bollard under load.

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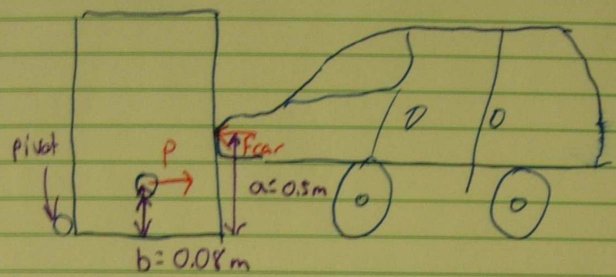
Saturday Jan. 10, 2009

Simplified calculation for force on load barring device



- According to situation above, this should be our higher design limit for load barring. Assumption: The bollard will not be able to fully stop a vehicle upon impact.

- For lower limit, we are considering the max force that a single person can kick @ (plus a safety factor buffer)

$$\Sigma M_{pivot} = 0 = b \cdot P - a F_{car}$$

$$F_{car} = \frac{b \cdot P}{a} \quad \text{or} \quad P = \frac{a F_{car}}{b}$$

Assumption: Lower limit design force = 5000 N = F
= 1124.05 lbf = F

$$P = \frac{(5000)(0.5)}{(0.08)} = 31250 \text{ N}$$

Use this # in FEA loading.

Shell

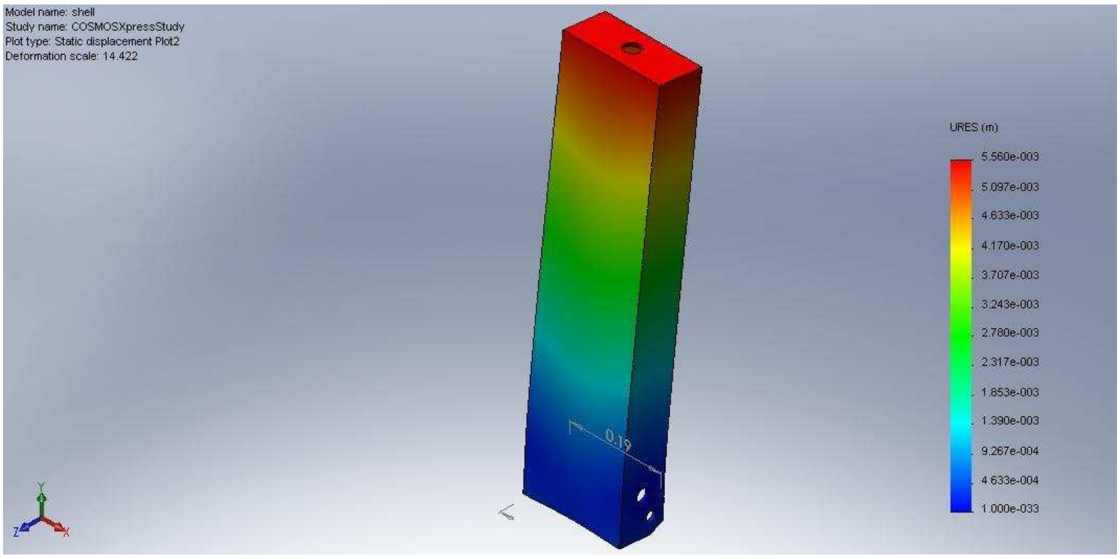


Figure 3.1 – Displacement Distribution of the Bollard Shell

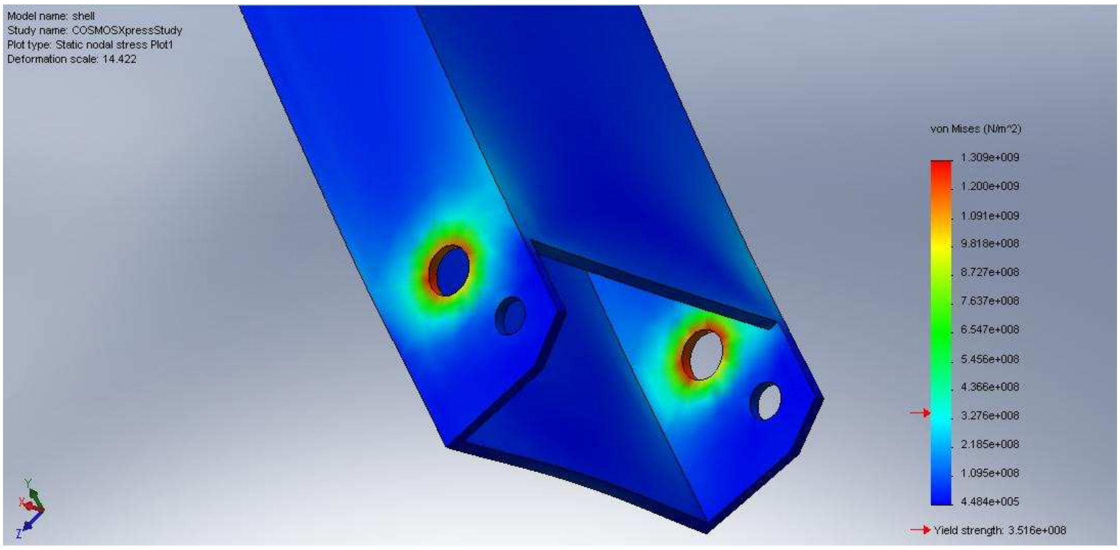


Figure 3.2– Stress Distribution of Shell

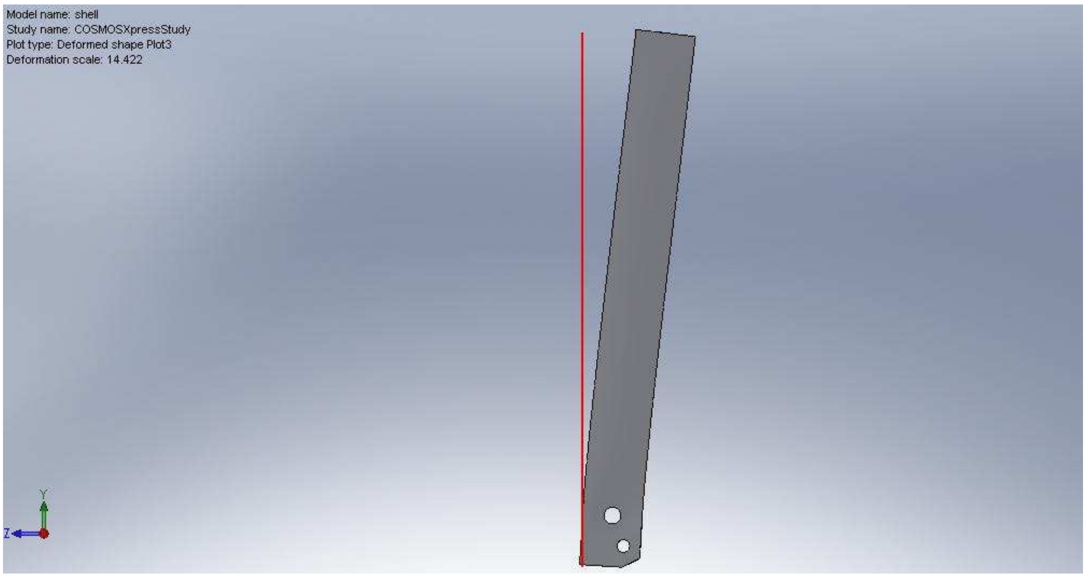


Figure 3.3– Shell Deformation Upon Loading

It is clear the hole for the hinge location is far too close to the edge of the bollard shell. Increasing the distance between the hole and the edge of the shell should be able to remedy the situation, as well as possibly increasing material thickness for that area.

Cavity Base

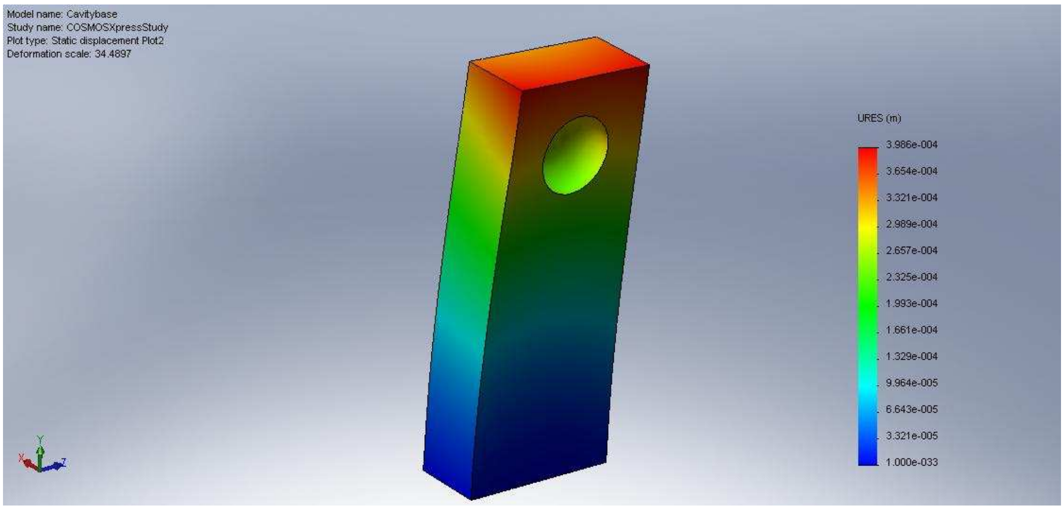
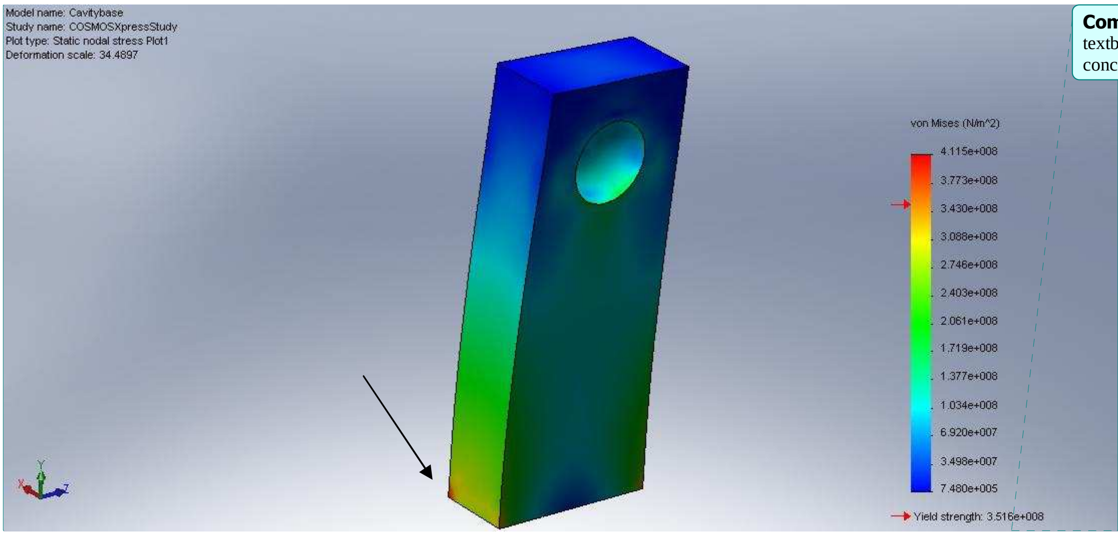


Figure 3.4 – Displacement Distribution of the Cavity Base



Comment [RS6]: Can't get a textbox to say "greatest stress concentration"

Figure 3.5 – Stress Distribution in Cavity Base

The greatest stress is seen at the bottom of the cavity base where it would be welded to the bollard base. Increasing the surface area of the bottom portion to have more weld area may remedy this situation. Since this is a worst case scenario in which the lock ball would not pop out of the cavity in this piece has the highest minimum safety factor, other areas would take priority in optimizing as they will break before this piece.

This shows that it is likely the first component to shear upon vehicle impact and potentially even under regular conditions before the lockball pops out of the cavity. The stress concentrations are shown where the hole and flat piece is connected to the cylindrical stock.

Lockball

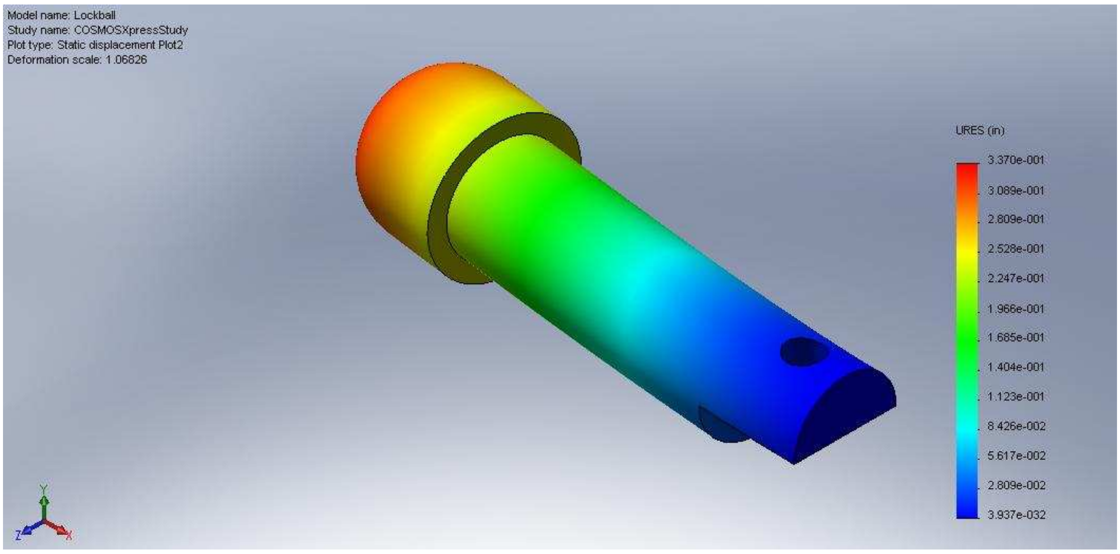


Figure 3.6 – Displacement Distribution in the Lockball

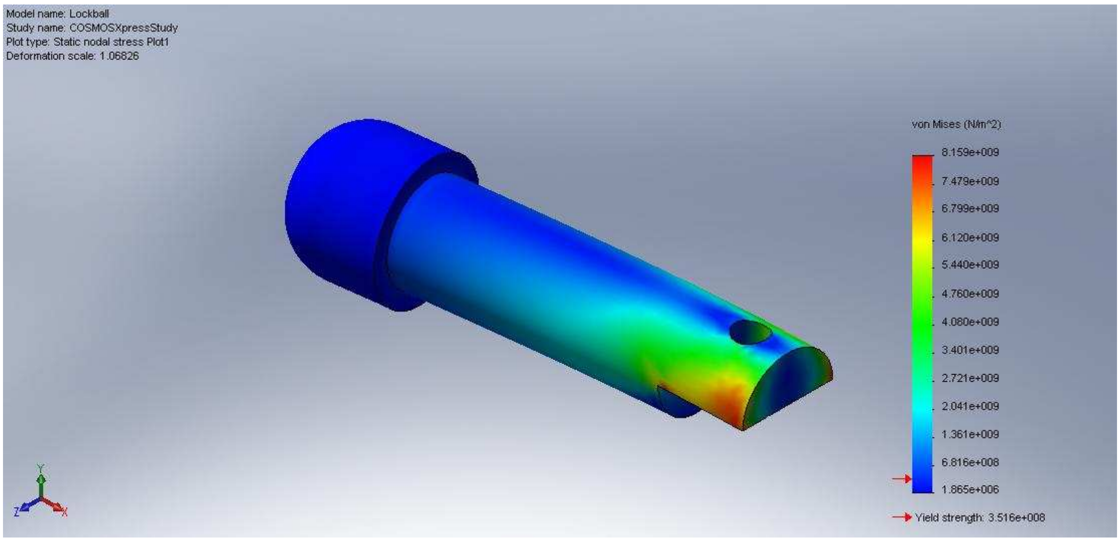


Figure 3.7 – Stress Distribution in the Lockball

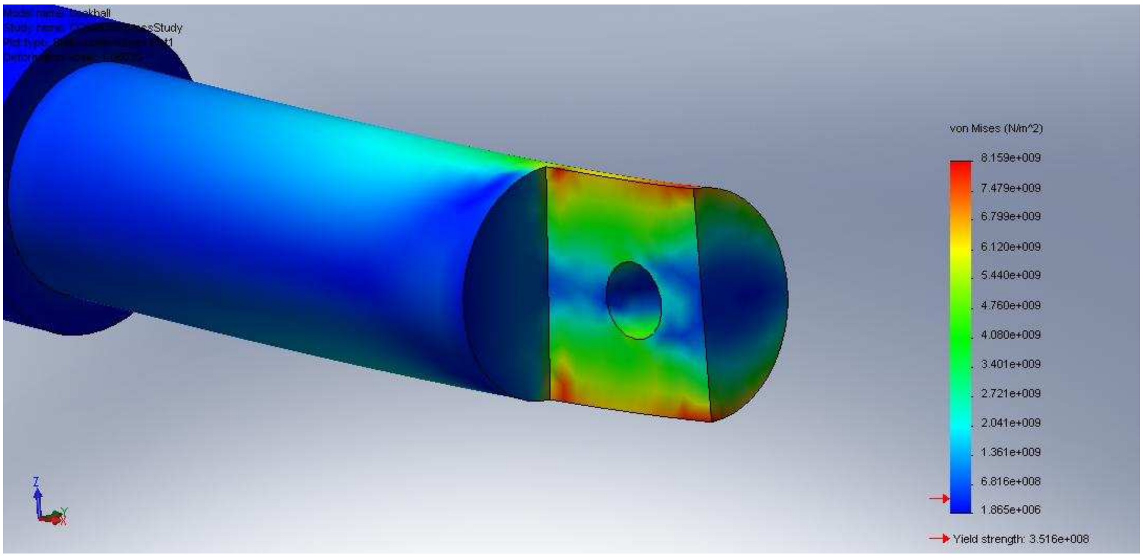


Figure 3.8 – Stress Distribution in the Lockball

3.1.2Hand Calculations

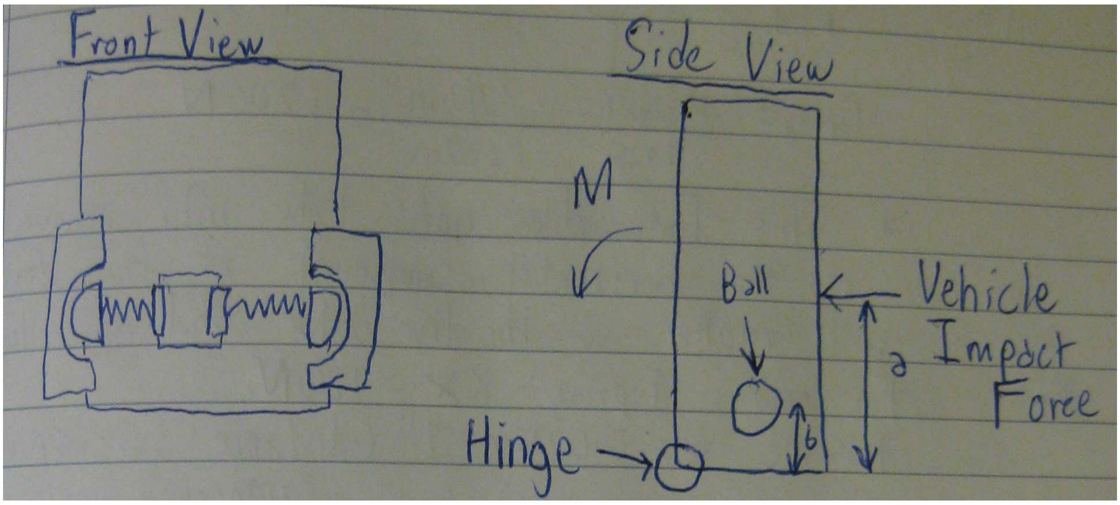


Figure 3.9

A Typical bumper to ground height is 16-20" ~ 0.5m

Set a = 0.5m, b = 0.08m

We need to determine a spring force which can comfortably turned by a human arm operating a fire hydrant wrench. Assume for now that 100N of turning force is within this comfortable range for a human arm. A typical fire hydrant wrench is approximately 0.3m long, so from here we can determine the moment force exerted from a human arm to the turning nut of the bollard.

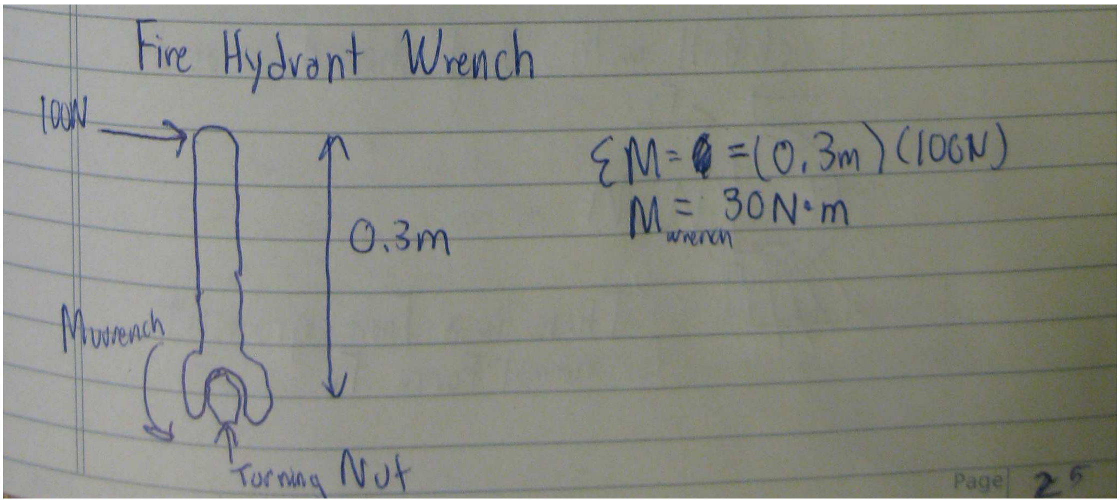


Figure 3.10

We find that M_wrench = 30 N*m

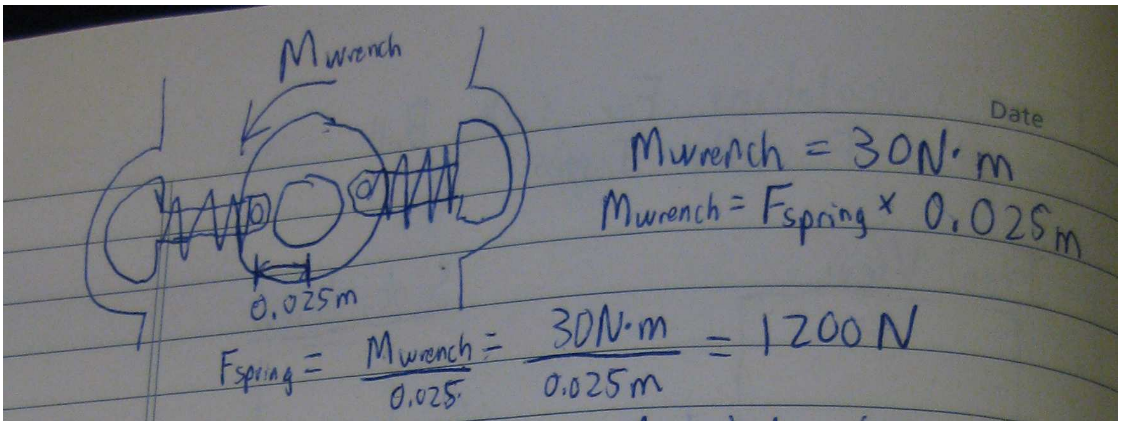


Figure 3.11

It is assumed for now that the turning nut is fully efficient in transforming the turning force into a horizontal compression force for the springs. In actuality it would not be fully efficient so the real life value of F_spring should be expected to be lower. From this simplified calculation, F_spring = 1200N.

Now the k value can be determined from equation F_spring = k*x where x is expected compression distance before popping out of the cavity, which for now will be assumed to be 0.025m.

So k = F_spring / x = 1200 N / 0.025 m = 48,000 N/m or 48kN/m.

This results in 24 kN/m per spring since there are 2 springs.

We know that F_spring is 1200N for both springs.

So the force required to compress a spring enough to move the ball out of the cavity is 600N.

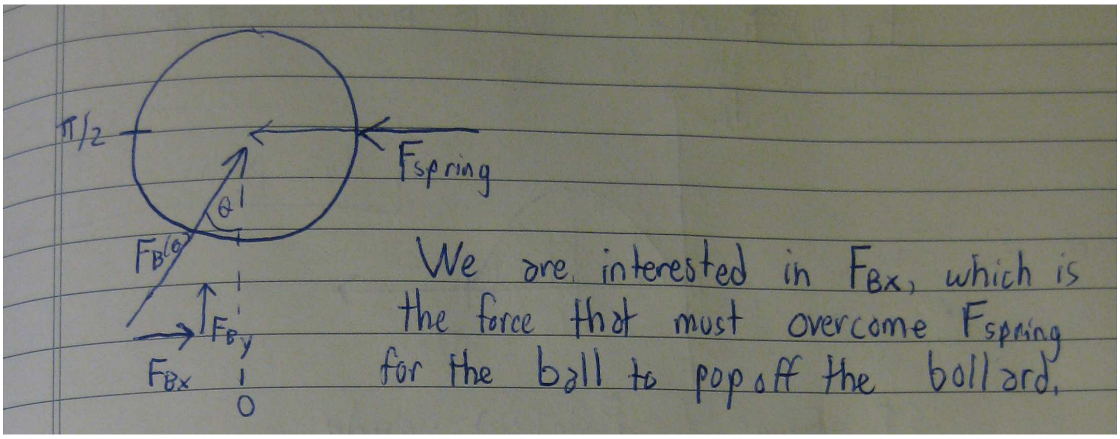


Figure 3.12

Since we know F_B(θ) is a function that forms a gradient as there are varying forces as we change the angle θ.

F_Bx = F_B(θ)*sin(θ)

For the sum of all x component forces of a given range,

$$\sum F\_Bx = \int_a^b F\_B(\theta) * \sin(\theta) d\theta = F\_spring$$ where a and b are the limits

I will have to make an assumption for 3 things at this point:

1. Assume a function for F_B(θ)
2. Assume the upper bound is pi/2 (ie. Forces beyond 90 degrees are negligible).
3. Lower bound is zero (Forces before 0 degrees are negligible).

Assume a conservative case where the cavity shape is not very flat, and the net resultant force is primarily at θ = pi /4 with the following shape:

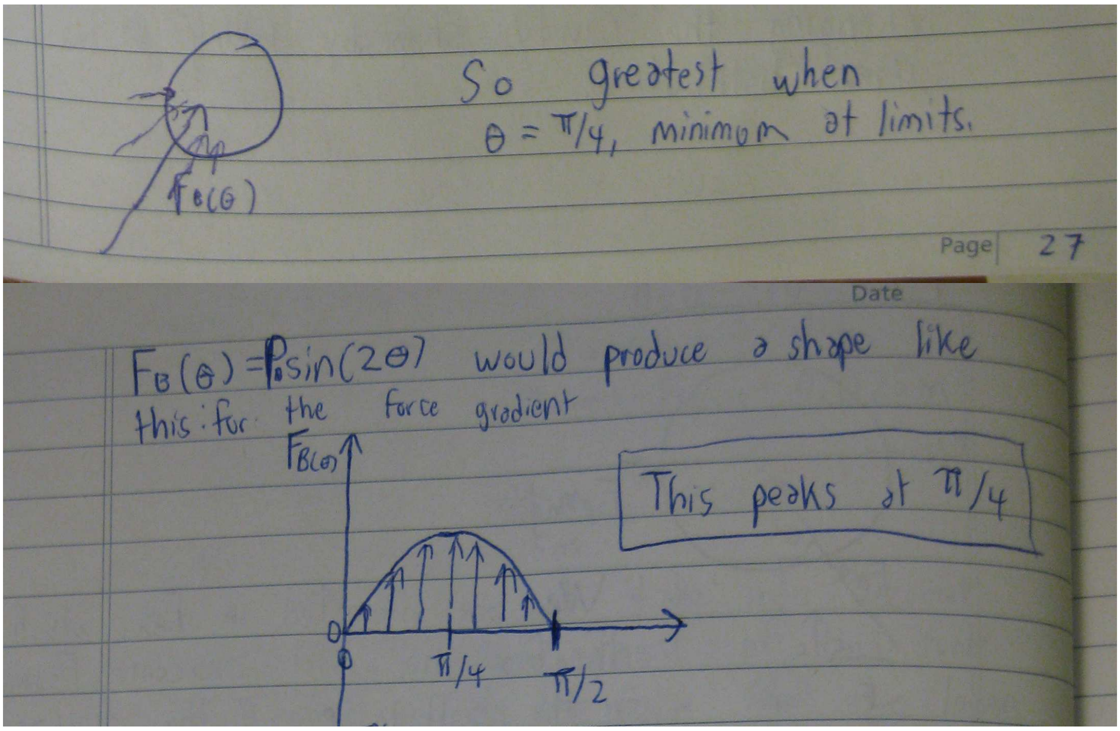


Figure 3.13

So the assumed function that would produce the above gradient would be

F_B(θ) = P * sin(2θ)   where P is the maximum amplitude of force in the cavity.

This comes out to the following equation:

$$\sum F\_Bx = \int_{0}^{\pi/2} P * \sin(2\theta) * \sin(\theta) d\theta = F\_spring$$

$$\sum F\_Bx = P\left[((-\sin(\pi/2) * \cos(\pi))/2) + ((-\sin(0) * \cos(0))/2)\right] = \mathrm{P}[1/2]$$

F_spring = 1/2P, 2*F_spring = P

So for F_spring = 1200 N, P = 2400N

This is the total normal force that would exist at the bollard cavity which would be effective in compressing the springs. We know that any vertical component form the normal forces would apply stresses directly to the hammers so too great a vertical force due to the shape of the cavity could cause the lockball to shear. The force P is applied assumed to be concentrated at the angle pi/4 in this example.

From this we have determined that the shape of the cavity influences the eventual effective compressive spring force. In this example we assumed a shape where the peak and majority of the forces occurred around pi/4 at the midpoint. If a function with the peak force so that the majority of the forces would occur around pi/16 were used, a greater resulting force P would occur.

Since F_spring or F_Bx will remain constant at 1200N, the vertical component, F_By, would be increased as well as the overall force P. We got with a conservative angle of 45 degree peak force that P would be 2400N. In an earlier calculation on page 22 we determine that a desired breaking force would be around 30,000 N. This is a magnitude of 10 times less than what is expected, but could be within reach if the angle is reduced. The main concern here would be whether the lock ball would shear or not due to these forces.

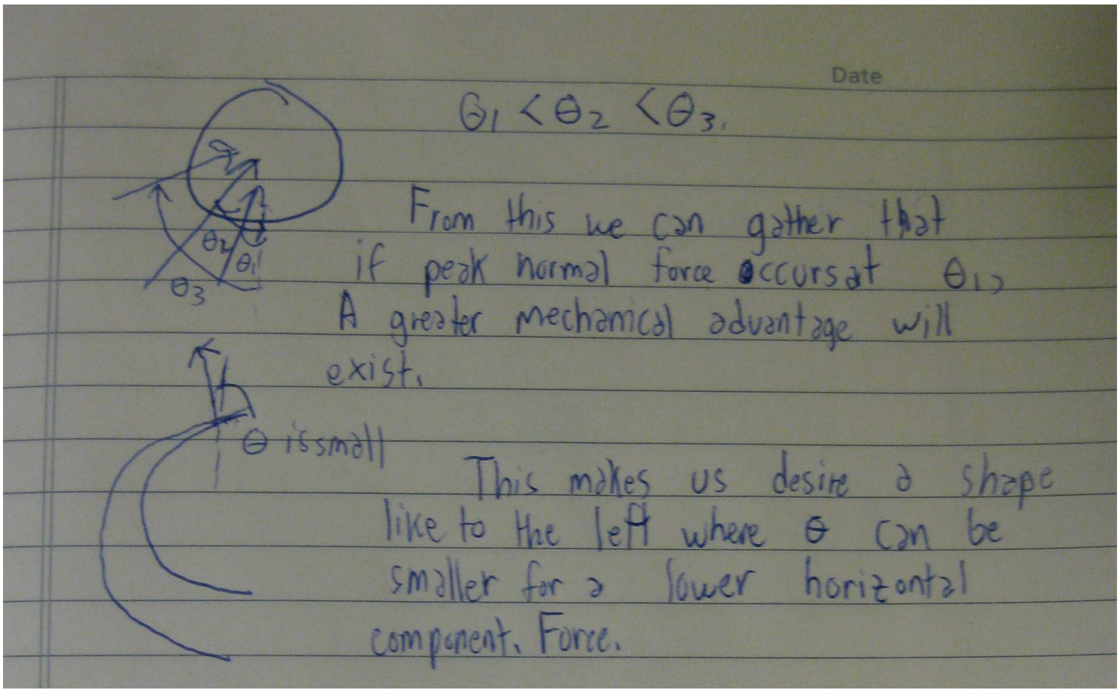


Figure 3.14

Some insight is provided here even though some assumptions had to be made. In particular, the relation between the stress distribution of the normal force on the ball and angle of overall normal force from the shape of the cavity. In the calculations it was assumed that the peak stress was located at 45 degrees relative to the spring force, and this was a conservative estimate. The end result was a very low force being required to knock over the bollard, but the shape of the cavity can be manipulated when it is being manufactured. It has been determined that if the peak force occurs at a lower angle θ, a greater amount of force will be required to pop the lock balls out of the cavity. It has also been determined that as the ball moves along the cavity and the area flattens out, the angle θ will tend to decrease thus increasing the mechanical advantage.

The trade off with decreasing θ is that the vertical component of the normal forces will increase, causing a greater amount of stress to the components of the bollard. If the vertical components increase too much then the lockballs themselves may break, as the FEA in the previous section indicated that the lockballs would likely be the first to break in this system. The other factor that can be controlled to increase the required force to disengage the bollard through impact is increasing the spring forces. The limiting factor here is the strength of the operator and it cannot be increased to a degree in which users cannot turn the nut with a fire hydrant wrench.

A shape such that θ decreases would ultimately call for more a more durable lock ball by increasing either its material thickness or using a stronger material for its construction. The final initial calculation showed a resistive force of only 384N for a given strength of springs. Several assumptions were made however so at best this can only be an approximation to the true force required to disengage the bollard through impact. Further empirical modes of testing as well as an in depth FEA analysis will be required to confidently confirm this calculation. If through a combination of the peak normal force angle and spring strength is changed, a much greater resistive force in the magnitude of thousands of Newtons may possibly be achieved.

3.2 Failure Modes and Effects Analysis (FMEA)

The FMEA indicates that the two greatest concerns would be deformation of the lockball and fracture of the spring due to corrosion cracking. All other failure modes are indicated below. The RPN column scores the failure modes with the highest areas of significance.

4.0 Conclusion

The basic geometries and interactions of the Lockball bollard design have been covered in this report. It has been concluded that there are two ways to influence and increase the amount of force required upon impact to pop the lockballs out of their cavities. The first option is in changing the shape of the cavity such that the sum of the normal forces acting on the lock ball would have a lower angle, which would decrease the horizontal component of the forces upon impact of a vehicle. This would make it more difficult for a vehicle to disengage the bollard for a given spring strength. The trade off to this is that the vertical component of the forces would increase if the angle were decreased, causing a greater amount of stress on the lockballs themselves. It has been determined through our FEA analysis that the lockballs would be the first to break if failure were to occur. Too much force distributed to the lockballs rather than the springs would increase the chances of the lockballs themselves shearing. To balance this, either larger lockballs with greater material thickness would be required especially in the flattened transition region, or to use material with very high strength.

The other method of increasing the impact resistance force is to increase the strength of the springs themselves. This is limited to what an operator could comfortably manually disengage by turning. Unless a mechanism where there is a mechanical advantage for transmitting the wrench force to axial spring compression is in place, these springs cannot be strengthened further.

Several assumptions were made in our calculations so complete confidence cannot be placed in the results. It is advised to spend more time performing a full FEA analysis on the cavity shape and lockball interactions. Some empirical experiments may also be required to confirm the feasibility of this design.

5.0 References and Appendices

All calculations and drawings in this document were produced by Shear Solutions.

APPENDIX A: Schematic Drawings

The following schematic drawings are provided in the following pages:

Bollard Shell

Bollard Base

Cavity Base

Lock Ball Unit

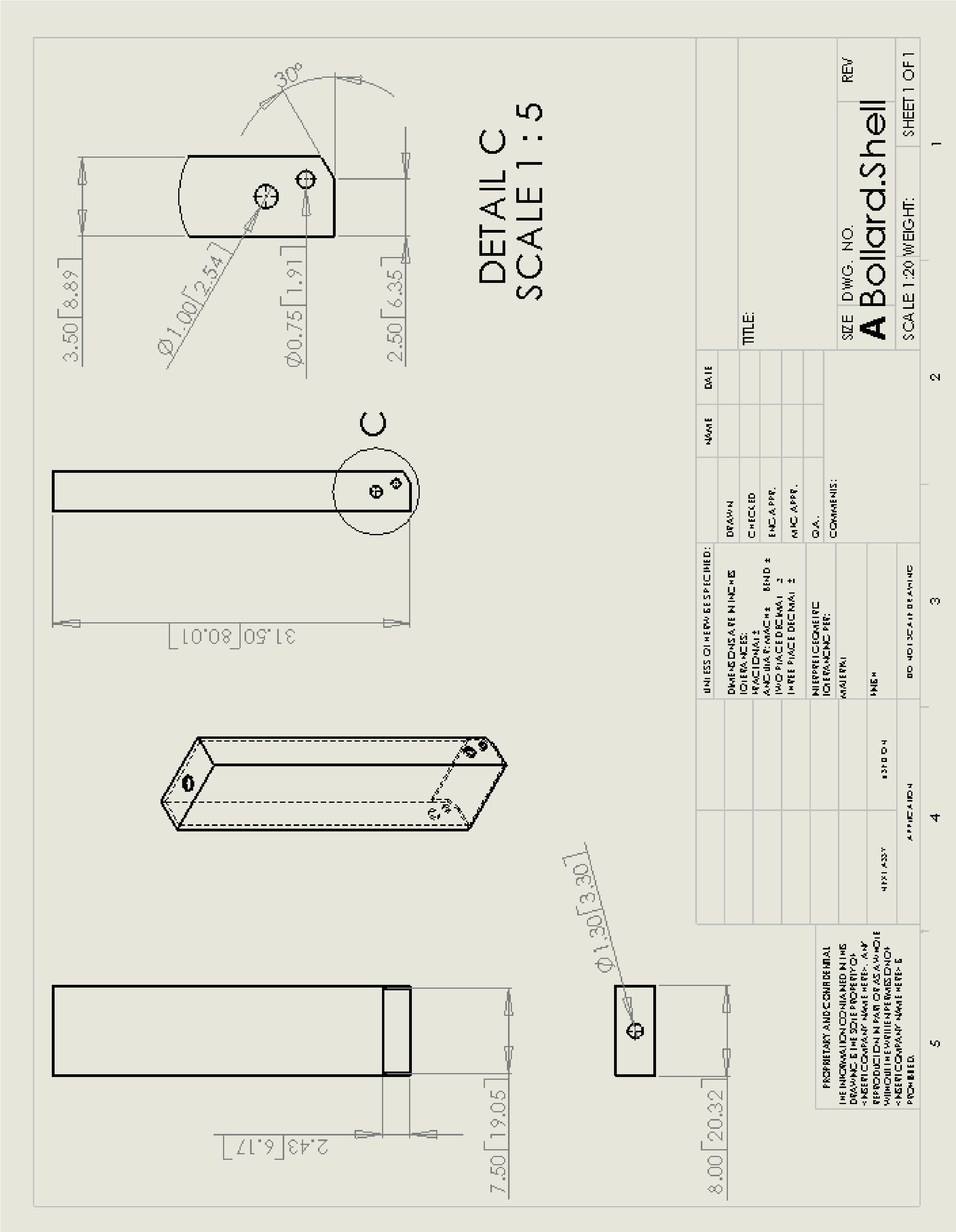
Linkage

Spring Support Brackets

Linkage Base

Hydrant Nut with Cylindrical Stock

Note: The unit of values within the brackets are in centimetres.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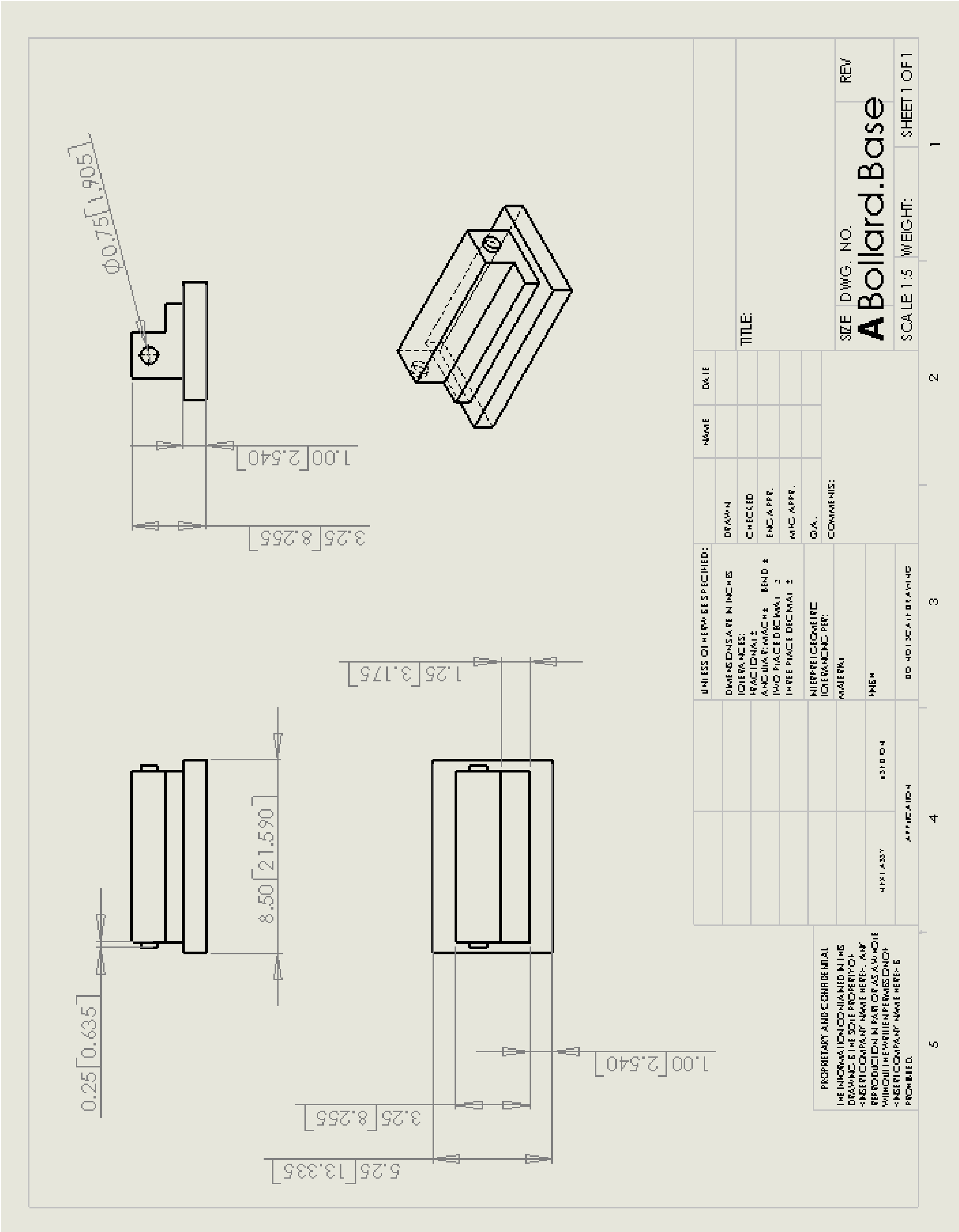

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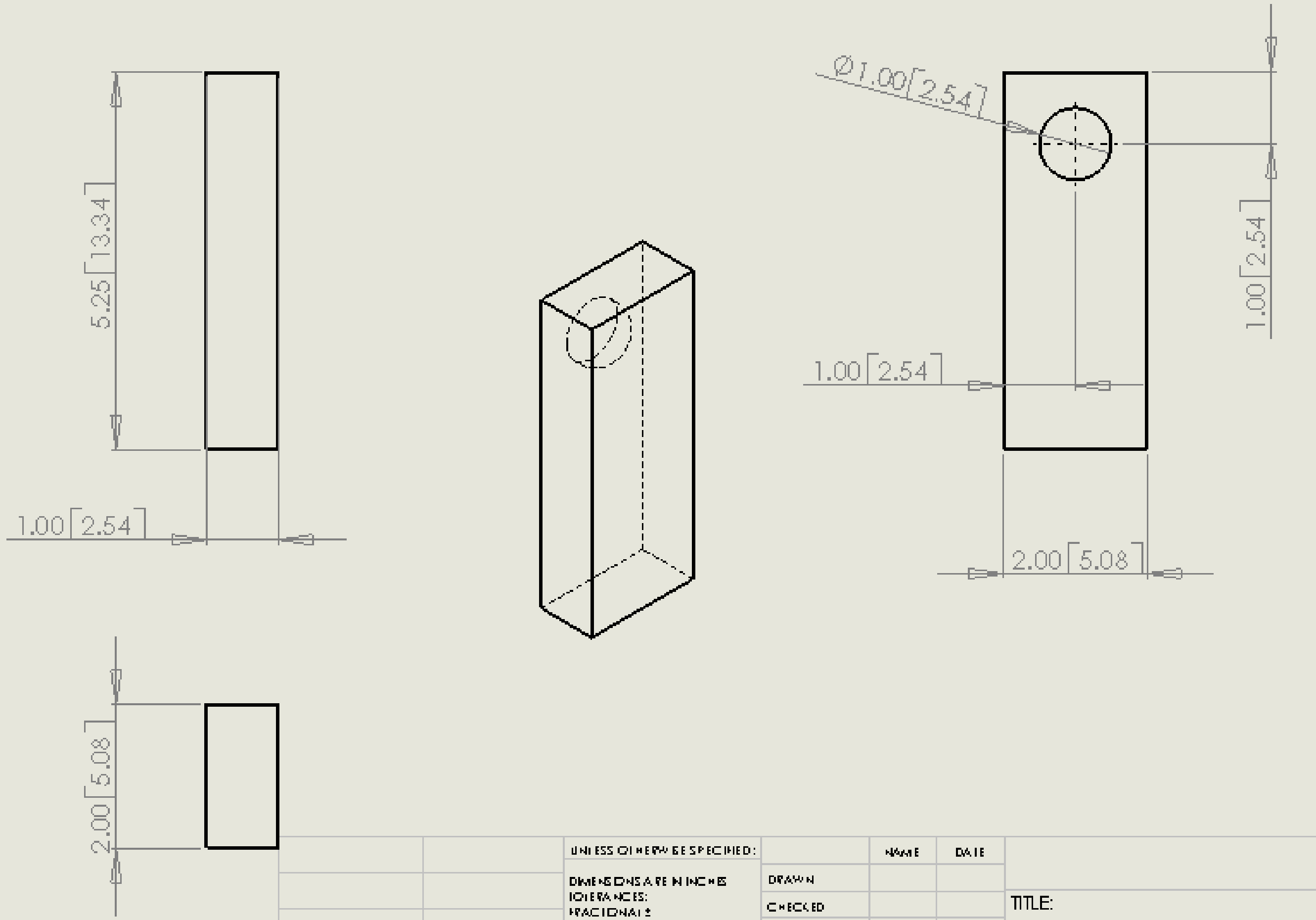

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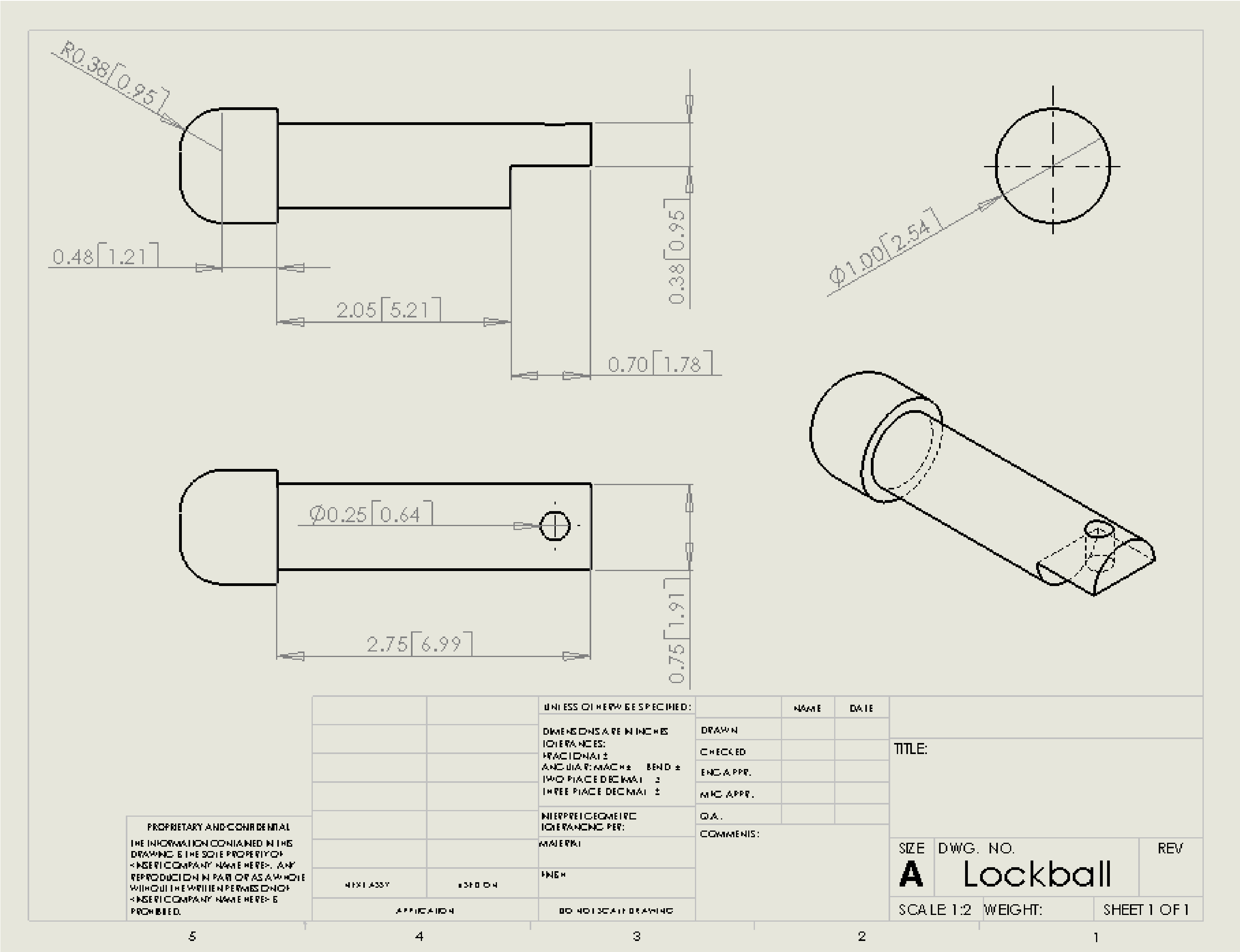
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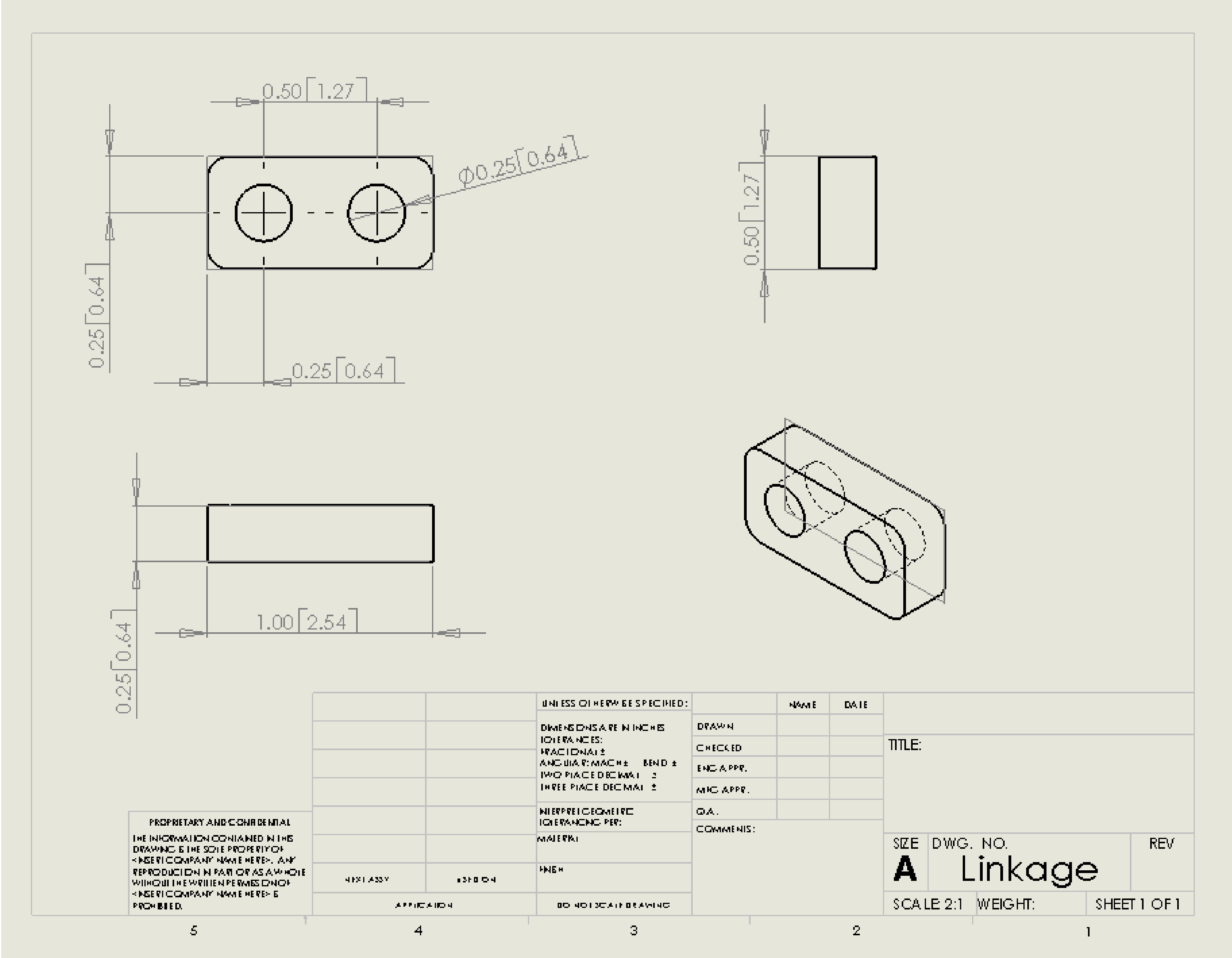
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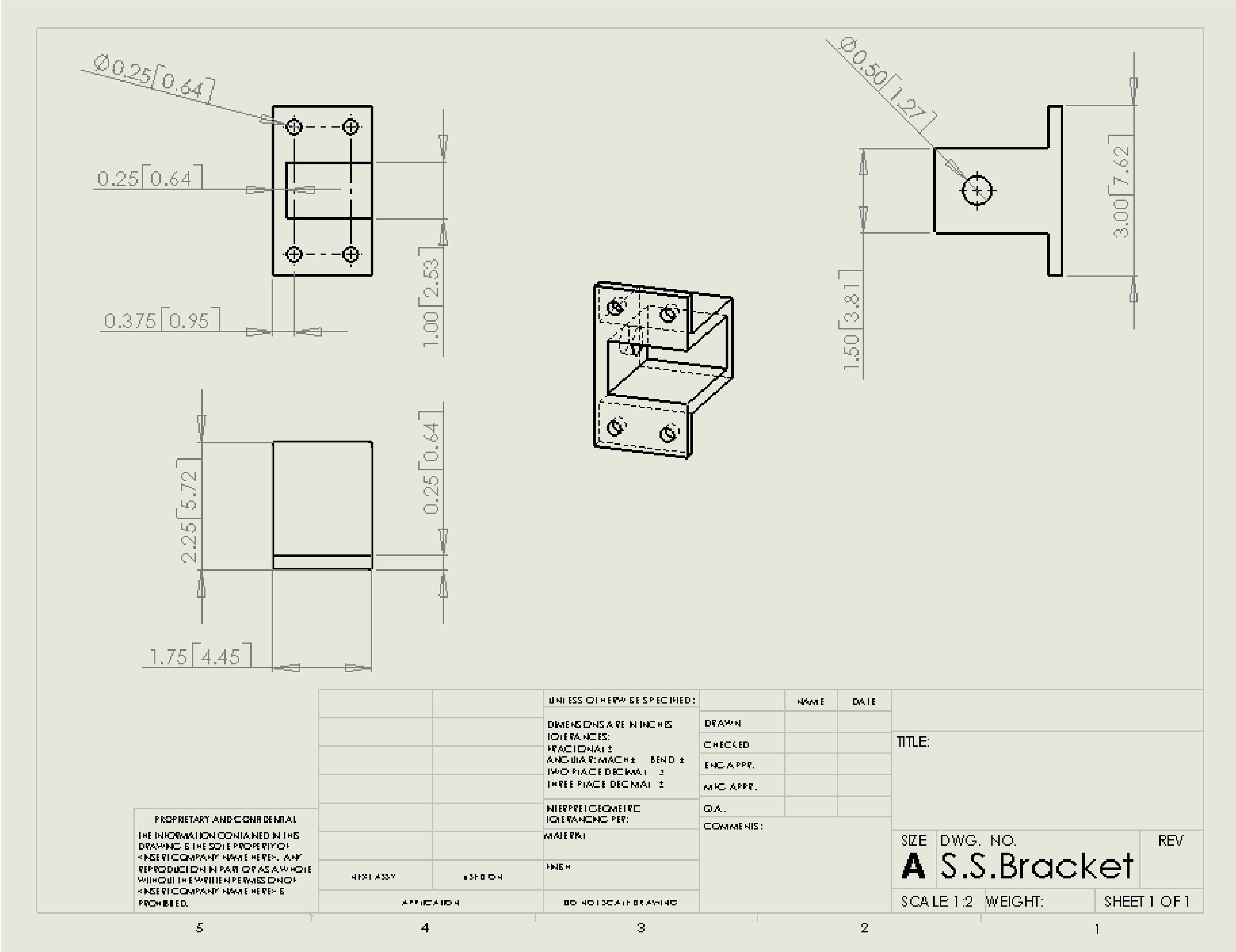
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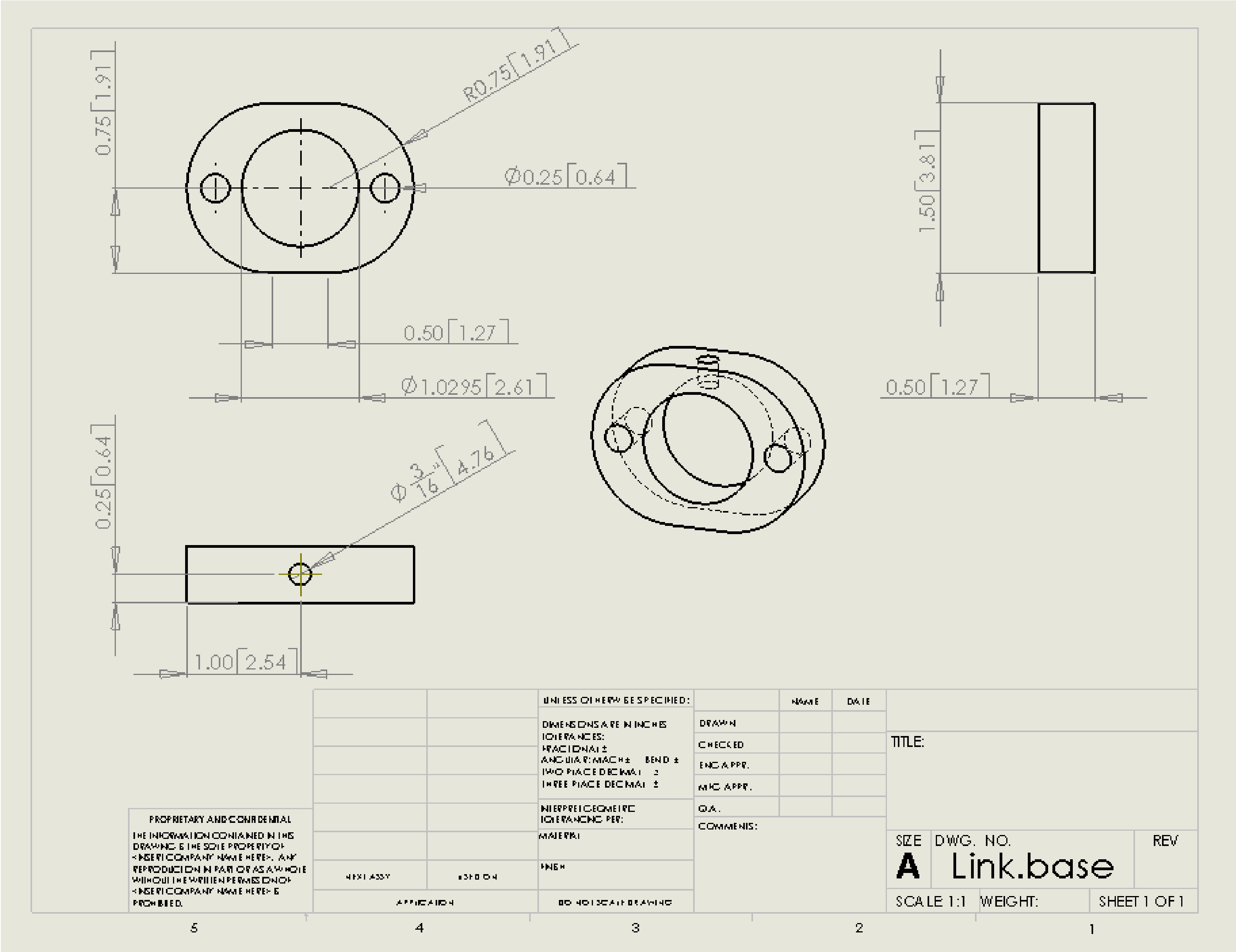
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Mech 457

Collapsible Bollard Prototype

David Ko
John Chang
Richard Situ

Date Submitted: February 6, 2008
Word Count:

The purpose of this critical function prototype was to determine whether the lock ball mechanism was viable using a physical prototype. It was concluded in the last technical analysis report that the calculations alone were not enough to prove the viability of this design due to the complexity of the forces acting between the ball and cavity surfaces.

Pictures and video footage of our physical prototype will be discussed and reviewed in the body of this report.

1.0 Identification, Importance and Abstract

The critical function that the design team has decided to prototype is the lockball force restraint system, as seen in Figure 1. The main objectives of building this prototype is to prove our concept's validity and to obtain some quantitative values of force for a given design. We will then use that data and incorporate design modifications to the final prototype, to reach the desired design conditions.

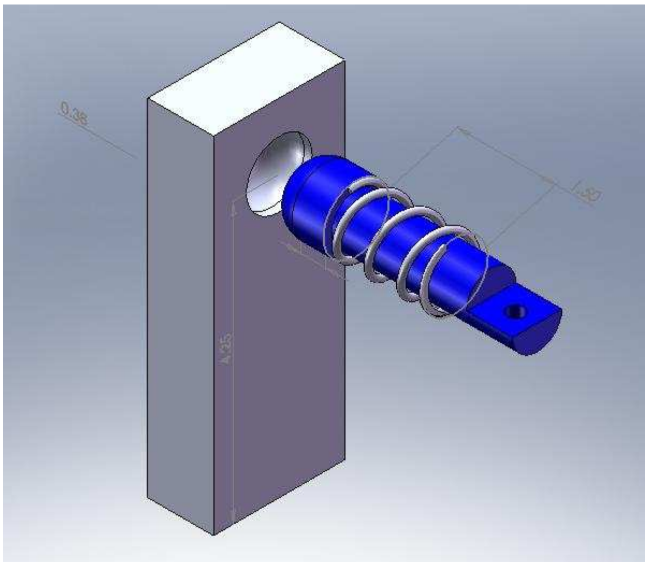

Figure 1.1 – Lockball Mechanism

The importance of the lock ball restraint system is monumental to the success of the design, given that this function encompasses almost the whole design (with exception of the manual disengagement linkage system). Without the lock ball restraint, we would have gone into a different direction in terms of the final product.

Insights that can be expected from this prototype have to do with the cup shape on the base, depth of lock ball entering the cup and the spring sized from the technical analysis report. The shallow-ness and chamfer angle of the cup will drastically affect the amount of mechanical advantage obtained when the whole assembly needs to resist the force of a car; doing the test at a certain angle and cup shape will give us a sense on what we need to change for the final design. The depth of the lock ball into the cup will be put into question because of the stress that the length puts on the frame of the prototype. Excessive stress before retraction may be the result and cause the prototype to break. Finally, when we did the analysis in our technical analysis report, we used a simplified control environment and assumed it would work in the real world. This may not be the case, which is why we may need to modify which spring we need to use after testing.

2.0 Documentation of Prototype

It is intended to model the disengagement/re-engagement mechanism of the bollard on a 1:1 scale with our intended design for the prototype. Only a single spring lockball will be modeled in this prototype as it should be sufficient to prove its viability. Parts of the bollard design that already seem feasible will not be modeled, unless it is a critical function for the lock ball mechanism. Parts which will be omitted include: The bollard shell, the turning mechanism which transmits torque from a fire hydrant wrench to a horizontal force to compress the springs in the lock ball.

Below is an illustration of the completed bollard prototype. A lever was added to simulate the moment force which would be applied by a vehicle's bumper striking the bollard shell. The manual disengagement and re-engagement method was simplified to a simple handle which is to be pulled to compress the spring.

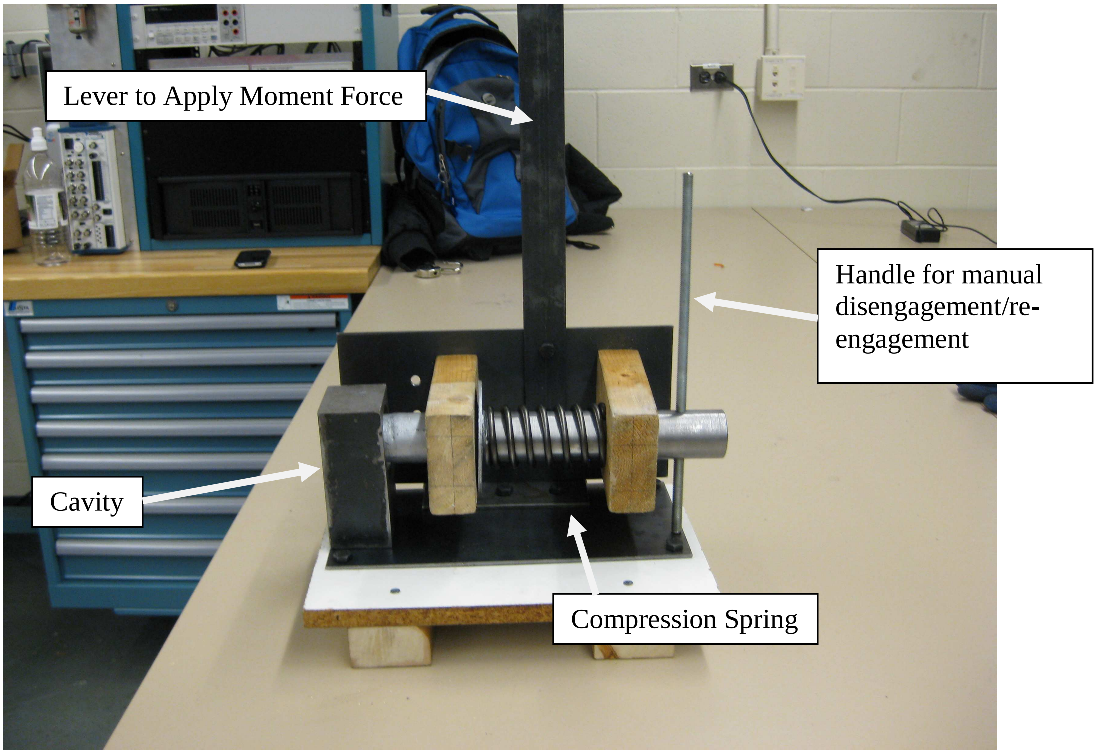

Figure 2.1 – Engaged Position of Lockball Mechanism

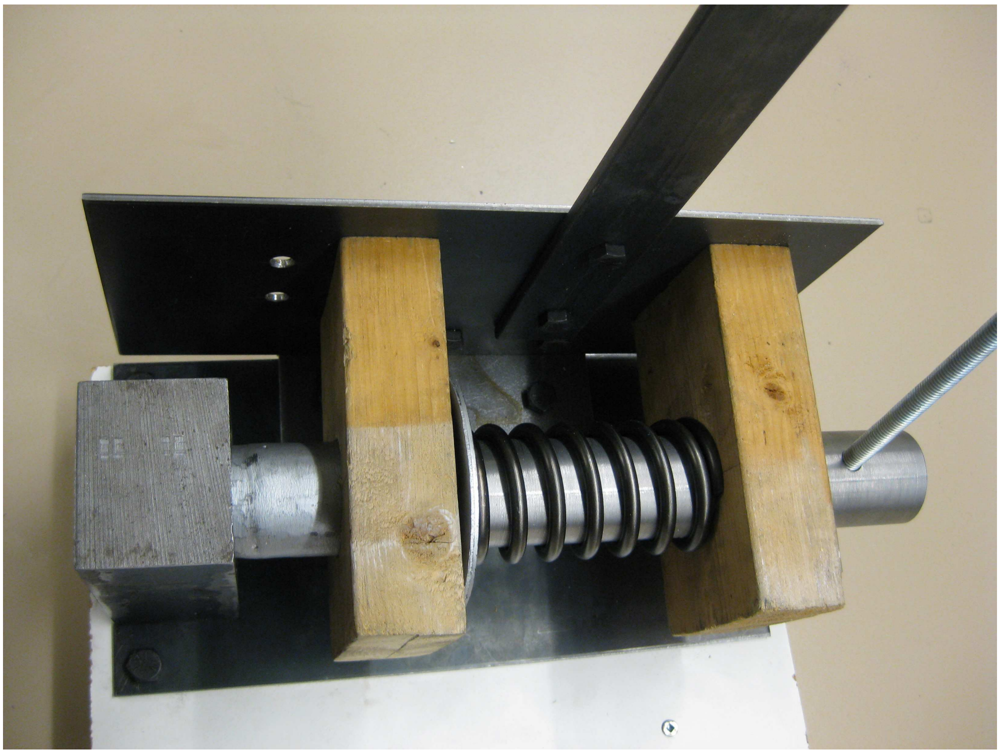

Figure 2.2 – Engaged Position of Lockball Mechanism

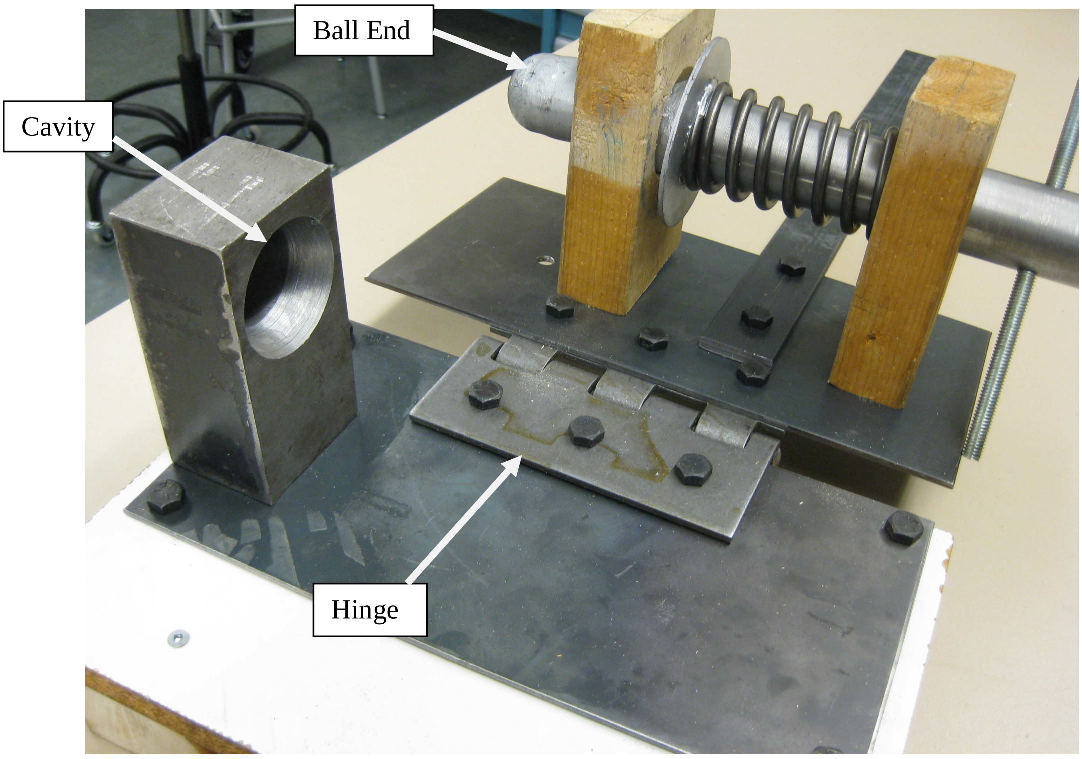

Figure 2.3 – Disengaged Position of Lockball Mechanism

In order to disengage this device the user would pull on the handle to compress the spring and allow the lock ball to be removed from the cavity. Video footage of this process is provided in the video:

Bollard_Manual_disengagement.wmv

Re-engagement of the bollard is performed in a similar manner. The handle is pulled back to compress the spring and allow the ball end to slide back into the cavity. Video footage of this footage is linked below:

Bollard_Manual_reengagement.wmv

Impact force of a vehicle was to be simulated by applying a horizontal force from the level at a similar height to a vehicle bumper. Video footage of this process is provided below:

Bollard_Manual_reengagement.wmv

It is apparent in the video footage that the wood used to mount the lockball mechanism is not sufficient to guide the mechanism as there is some deflection and the wood screws are not holding. The wood will be replaced with welded sheet metal to increase the strength and the accuracy of this physical prototype. Until this prototype is updated the results of these experiments will be inconclusive.

3.0 Test Documentation

<u>Test: Bollard Pull Test</u>

<u>Objectives</u>: - To prove feasibility of lock ball concept
- To measure approximate force required to disengage prototype

<u>Equipment</u>: - Prototype
- Force Gauge
- Lead Weights
- 5-8 ft of chains
- Ratcheting Come Along

<u>Procedure</u>:

Part 1: Concept Validity

1. Secure prototype to ground using lead weights
2. Attach one end of the chain to the top of the rod extending the prototypes effective lever arm.
3. Attach other end of chain to the ratcheted come along.
4. Allow approximately 6 ft of chain to be put into tension between the prototype and the come along.
5. Start to ratchet the come along until movement of the lock ball begins.
6. Slowly increase the ratcheting until full disengagement is obtained.
7. Once disengaged, release tension on the chain, push prototype into engaged position.

Part 2: Force Measurement

8. Take end of chain that was attached to come along and attach to the force gauge.
9. Attach force gauge with another chain, to the come along.
10. Attach as pointed out in figure
11. Repeat step 6, read force reading from gauge at disengagement point
12. Repeat step 7

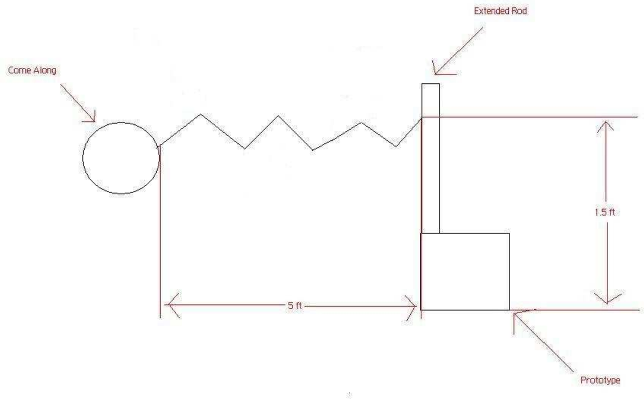

Figure 1.2 Validity Test

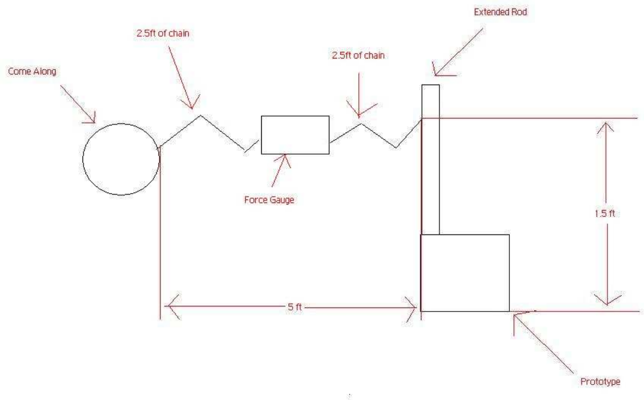

Figure 1.3 - Force Measurement

4.0 Quantitative Analysis and Assumptions

5.0 Considerations for the Future

Quantitative analysis of the results and a discussion of possible errors assumptions and resultant limitations of the analysis.
Unfortunately at the time of testing prior to having this report submitted in, we were unable to quantify our test results and determine the amount of force we need to completely disengage our prototype. With that in mind, we were able to conclude that the concept worked. A few limitations of our analysis is the physical size of our chamfer hole in the cavity base. The degree of chamfer will dictate the amount of force necessary for the bollard to disengage. If there is no chamfer, it is highly possible that the lockball unit would not slide out but have a large enough bending moment on it to cause it to break.

Future Steps

There are a few things that need to be done now that we have finished building and testing the critical functioning prototype.
Modifications of the cavity base hole may be necessary after testing the critical functioning (CF) prototype. The lockball unit and cavity base unit were able to disengage after applying enough physical force generated by one man. A decrease in angle protruding into the cavity base to 10 degrees from the current 20 degree angle may secure the lockball unit more effectively in the cavity base unit.
During testing, the two wooden guides for the lockball unit started to break away from the wood screws causing the lockball unit shift from the back plate that it was connected to. This may have caused the disengagement to occur under lower forces then intended. To correct this malfunction, we plan to replace the wooden guides with ¼’ steel plating that will be welded on to the back plate connecting to the hinge. With secure guides for the lockball unit, accurate force measurements and testing can be conducted without having any parts prematurely failing.
From this point on, we will be further refining the design of the linkage mechanism and start manufacturing those parts. Materials needed for the disengagement mechanism may change depending on cost and availability.