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SYSTEMATIC REVIEW

An Experimental Study of Improvised Portable Manual Rebar Bender

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Abstract

Objective: To design, fabricate and evaluate the new features of a portable manual rebar bender, a Hand Tool that is used for bending rebar and other malleable materials. **Methods**: The researcher improves on the previously available portable manual rebar bender. Experts assessed the acceptability of this bender in terms of design and portability. Furthermore, as previously stated, the study significantly improves the usefulness of the inexpensively produced bending machine for reinforcing concrete with negligible human force. **Findings**: The device created has a valuable impact on the construction industry's human force due to its affordability and marketability. Also, the present tools guaranteed strength, durability, and lightness in weight. Furthermore, the portable manual rebar is made of different elements such as a center axle, stationary backup roller, and sleeve. The results after ten trials showed that the portable manual rebar bender could finish 9 mm, 20 mm, and 12 mm stirrup at an average of 24.3 seconds, 26.3 seconds, and 27.7 seconds, respectively. Additional results from seven to ten trials showed the bending time for 24 seconds stirrup for 9mm, 26 seconds stirrups for 10 mm, and 28 seconds stirrup for 12 mm. Furthermore, after a series of ten trials, the instrument achieved an accurate angle bent of 90 degrees. The M= 4.77 and 4.82 are very acceptable in terms of design and portability tools based on the evaluators' rating. **Novelty**: The design is novel in terms of cost, portability, and efficiency. The device can be a great help in the structures and buildings. Furthermore, the construction industry will use the portable manual rebar bender to build houses and other local infrastructure to test its effectiveness. Then, the researcher is encouraged to engage in another research to try the innovation.

Keywords: Improvised; Innovative; Locally made; Device; Bender

1 Introduction

Nations development today depends on infrastructures such as skyscrapers, roads, bridges, etc. Construction of concrete started in ancient civilization but reinforced with steel and bars only begun in recent times [1]. Currently, experts and scientists developed simple techniques in inserting vertical steel [2]. Nowadays, there are varied rebar benders in the market, such as manual rebar bender, portable rebar bender, electric rebar bender, hydraulic rebar bender, and automatic rebar bender. Most of these have specifications that go with the latest state-of-the-art of the industry. These are equipped with computer software and powered either by a hydraulic motor engine or electricity. This equipment is designed for the production of rebar off-site.

Hence, they are not portable and cannot address the need for rebar bending in the job site, especially in the countryside[3]. The reinforced concrete industry has evolved over the years from the early 1900s[1]. Originally, humans used physical force like hand and feet to bend the steel rods[4]. Commercial benders are available in the market that bends all standard sizes of rebar in the trade quickly and precisely using less human effort than conventional techniques. Some are electrically powered bender and hydraulic bending machines but costly and not portable. The portable manual rebar bender was specifically designed to address the existing problem of small construction firms and contractors in places where there were construction works regardless of geographic conditions and terrains. This is developed from the principles and mechanisms used by companies worldwide engaged in manufacturing of hydraulic and electric powered rebar and portable bending machines. It is conceived and engineered to provide a portable manual rebar bender that transcends the conventional ways of bending rebar, an essential component for concrete reinforcement. The tool provides the steel man with easy and efficient ways to produce rebar in the job sites. This utility model provided an effective and viable alternative for small contractors engaged in construction works to produce rebar efficiently with minimal expenses. It offered small construction firms the opportunity to acquire portable manual rebar benders that were affordable and marketable.

Technology and innovations advances in 2000 in this scrappy society become an international debate in the scientific community's social studies. These debates are focused on how to conceptualize a technology, the question of human agency and response to the provocations, and turns to microstudies and more comprehensive perspectives[5].

A rebar bender/cutter is a tool for shaping and cutting. The conventional tool such as manual bending is a little risky and can cause injury to workers in the construction sites. To increase safety and prevent human damages, builders invent new technology, like rebar bender, that can bend even the most challenging steel bars in few seconds in specific angles. Thus, recent innovation plays a significant role in the construction industry[6] but a little expensive. However, in this study, the researchers created a portable manual rebar bender using cheaper materials.

The instrument comprises a horizontal base, a supporting flange extending vertically from that place, and an arm receiving cam[7]. The use of computer-integrated construction or CIC can impact the construction industry. Thus, reinforcement bars or rebar can be improved by the utilization of a computer system. But embracing more state-of-the-arts needs to be portable[8].

For instance, portable rebar bender is one of the astonishing discoveries that have come out in the industry.

The bender is famous for its unique and compelling and is designed to bend rebar from various angles from 0 degrees to 180 degrees quickly. But the portable hydraulic rebar bender is broadly applied in construction projects for its convenience to move and has an excellent performance[9]. But in this study, the researcher suggested cheaper and accessible methods to create a rebar bender which is beneficial to the small construction industry.

Workers in charge of cutting and bend rebar face danger and hazards. Lifting heavy materials can cause muscle pain or injury[10]. Thus, it requires proper procedures and protocol in this industry. Hence, Filipino engineers, experts, and innovators create equipment that is portable and easy to access. This study's current bender generally relates to concrete reinforcement steel bar bending tools in the concrete industry. It may be used for any other appropriate type of rod, pipe, tube, or malleable material bending. These devices easily turn all common sizes of rebar in the trade quickly and precisely using less human effort than conventional techniques but lack portability. There is also underlying weakness in steel rebar's, such as susceptibility to corrosion or oxidation. When exposed to salts, chemicals, or moisture, it can easily be destroyed[11]. Thus, training for a novice is essential to make them experts in the field[12] and save money, time, and materials[13]. Also, even automated bar bending that gives productivity can result in inaccuracies in quantity estimate[14].

To invent this kind of technology, understanding the parameter skill is required[15]. This study is a portable manual rebar bender specifically designed to address small-scale construction firms and contractors in the Philippines. During this pandemic, people become innovative and creative to create protected materials. The first months of the COVID 19 crisis resulted in a shortage of equipment and facilities[16]; thus, innovating is the current trend in this new normal.

Colorimetric logic design utilizing YES/NO logic gate, there are some improvised explosives like nitrate-based improvised explosives, black powder (BP), ammonium nitrate (AN), urea nitrate (UN), and their related constituents[17].

This is developed from companies worldwide' principles and mechanisms engaged in the manufacturing of hydraulic and electric powered rebar and portable bending machines.

The lack of studies about this concept motivated the researcher to engage in this study. Hence, this study aimed to design, fabricate and evaluate the portable manual rebar bender.

2 Methods

2.1 Design Criteria

This project study deals with a Portable Manual Rebar Bender whose design was an innovation of the existing prior art and was subjected for evaluation as to acceptability in terms of design and portability.

The test criteria are capability (no. of bends/time), accuracy (angle and size), speed, and efficiency (time/bend).

2.2 Design Plan Preparation and Fabrication

The tool was constructed in one of the Machine Shops in Estancia, Iloilo. The design was an innovation of the existing prior art, specifically the "Heavy Duty Bend Machine Electric 1" (#8) 25 mm Rebar Bender, which can bend rebar up to 180 degrees. This Rebar Bender is being advertised online (www.ebay.com/itm/Heavy-Duty-Bend Machine-Electric 1-8-25mm-Rebar-Bender-Bend-180 Degrees-Shop-350759917214. The identified disadvantages of the prior art presented in this study served as bases for the researcher to conduct this study, hoping that the tool's parameters will be improved and acceptable in the local settings within the country. The construction materials of the tool were carefully selected to ensure that it could withstand repeated stress during the actual operation.

2.3 Fabrication Procedure

In the planning design stage, the researcher spent considerable time and effort reviewing the existing prior art features to decide what materials to be used and procedures to employ in constructing a portable manual rebar bender. The design plan of the portable manual rebar bender was prepared right after the analysis and evaluation of prior art. The materials and supplies needed were secured; fabrication of the tool was initiated based on the drawing plan's specified design.

2.4 Evaluation procedure

The fabricated portable manual rebar bender was evaluated in terms of its technological usability, actual test using the design criteria, and level of acceptability using the self-made research instruments. Before using the research instrument, it was subjected to validity and reliability testing to determine its statistical accuracy.

2.5 Pilot Testing and Revision

After the fabrication of the bender, it was pilot tested on December 11, 2019, to determine the flaws and setbacks observed during the tool's operation.

The researcher keenly observed how the tool operated and willingly received suggestions from the evaluators during the said pilot testing. The test was geared towards the capability of the bender, accuracy, speed, and efficiency.

The accuracy of the bender was determined based on the angle being produced during the bending and the sizes of stirrups and ties. In terms of timeliness or speed, the time per stirrup was determined by actual operation and was compared to the speed of existing designed handheld rebar bending tools and bending machines. A weighing scale was used to determine the tool's minimum and maximum weights for the portability feature of the portable manual rebar bender. The test of capability was determined based on the number of stirrup per time.

2.6 Technical Evaluation

After the pilot testing and revision, the tool was presented to a panel of technical experts. This evaluation was necessary to determine the technological issues of the fabricated portable manual rebar bender.

2.7 Instrumentation

To find out whether the study's objective is achieved, self-made questionnaires (research instrument) were used, and the 5-point Likert scale ascertained the level of acceptability in terms of the design and portability of the rebar bender. Experts in the fields validated this questionnaire.

The accuracy of the tool will be determined based on the angles being produced during the bending operation of the tool and the sizes of the stirrups and or ties. The 5-point Likert scale will be used to determine the accuracy of the angle based on items specified in the instrument. The researcher will devise a rating scale to determine the accuracy of the desired angles and sizes of stirrups and or ties.

A weighing scale will be used to determine the minimum and maximum weight of the tool. In terms of the tool's acceptability, the researcher-made instrument will be used together with the result of the technical evaluation, specifically on the design, operation, accuracy, portability, and timeliness of the tool. The questionnaire to be used for the final evaluation will be provided with five choices:

Highly Acceptable with a scale of 5; Very Acceptable, 4; Acceptable, 3; Fairly Acceptable 2; Not Acceptable with a scale of 1. An arbitrary scale describing the level of acceptability will be provided by the researcher.

2.8 The Evaluators

The evaluators were the ten (10) steel men, five (5) Foremen, five (5) Engineers, and five (5) construction suppliers from different small construction firms within the Municipality of Estancia, Iloilo.

This study employed the use of purposive sampling. A form of non-probability selection in which decisions concerning the individuals to be included in the sample was decided by the researcher, based upon a variety of criteria that included the specialist knowledge of the research, issue, or capacity willingness to participate the study.

2.9 Validation Procedure

The research instrument was designed to measure the portable manual rebar bender's acceptability, particularly was submitted to the panel of examiners for validation. The jurors were composed of five experts, namely, two (2) experts from the construction industry, two (2) authorities from the field of research, and one (1) English critique.

The instrument was administered to a group of twenty-five (25) persons having similar nature of jobs, specifically to those who are involved in the construction works such as project engineers, foreman, and steel man before it was submitted for final evaluation of its acceptability.

2.10 Performance Parameters

Parameters within the context of this research study refer to the acceptability of the portable manual rebar bender in terms of its capability, accuracy, speed, efficiency, design, and portability to provide small scale construction firms and activities an affordable and viable tool. Furthermore, it can address the need for a portable yet efficient bender. Performance parameters and constraints were; capability, accuracy, speed, and efficiency of the portable manual rebar bender. The data gathered were made the basis for determining its actual performances.

2.11 Cost Analysis

Table 1 shows the breakdown and lists of materials and costs of fabricating the portable manual rebar bender. The cost of labor and supervision were also included.

Table 1. Material, labour and machining Cost

Materials	Size	Qty	Unit	Unit Cost PHP	Total Cost PHP
Steel Plate	7" x 25"	1	Pc.	490.00	490.00
Steel Plate	4" x 12"	1	Pc.	140.00	140.00
Steel Bushing	40mm∅	1	Pc.	200.00	200.00
High Carbon Steel Pin	32mm∅ x 100mm	1	Pc.	150.00	150.00
High Carbon Steel Pin	12mm∅ x 75mm	1	Pc.	50.00	50.00
G.I. Pipe	25mm∅ x 6"	1	Pc.	50.00	50.00
Machine Bolt	12mm∅ x 1 1/2"	1	Pc.	7.00	7.00
Machine Bolt w/ nut and washer	10mm∅ x 1"	1	Pc.	5.00	5.00
Plain washer	4" Θ x 1/16" Thk	1	Pc.	10.00	10.00
Plain washer	1 1/4" Θ x/16" Thk.	1	Pc.	5.00	5.00
Log Screw	3/8"Θ x 1"	4	Pcs.	5.00	20.00
					Material 1, 137. 00
					Labor and Machining 3, 600. 00
					Total Cost **PHP 4, 737. 00**

The above table shows the material cost, labor, and machining cost. The expenses amounted to three thousand six hundred pesos (PHP 3, 600. 00). The overall cost of the portable manual rebar bender is four thousand seven hundred thirty-seven pesos (PHP 4, 737. 00).

3 Results and Discussion

3.1 Design and Fabrication of the Portable Manual Rebar Bender

Typically the device comprises of at least one steel base plate 15mm thick (1), a 25 100mm diameter by 15mm thick rotary steel plate (2), the 40mm diameter steel bushing (3), a 32mm diameter high carbon steel pin (4), a 15mm diameter high carbon steel pin(5), one 15mm thick lever handle (6), one 25mm diameter G.I. Pipe handle (7), 15mm thick rebar adjustable guide (8), 15mm thick rebar guide plate (9), 12mm bolt with plain washer (10), a 10mm diameter bolt with nut stopper(11), nine 10mm 30 diameter measuring hole (12) in the steel base plate (1), one 6mm∅ diameter bolt with nut and plain washer (13) place at the end of the lever handle (6), and at least one adjustable measuring guide (14), 100mmdiameter by 6mm thick plain washer (15), four 6mm diameter holes (16a, 16b, 16c, and 16d) in the 15mm thick steel base plate (1), a 6mm diameter grease nipple (17), one 32mm diameter hole (18) in the steel base plate (1), two 25mm by 225mm holes (19a and 19b) in the steel base plate (1), and one 40mm diameter hole (20) in the rotary steel plate (2), and one 15 mm diameter hole (21) in the 15 mm thick rotary steel plate (2), and precut size of the rebar (22).

The device may be adjustable to vary the device's dimensions for different sized materials to be bent. The present device was fabricated from steel, machined shop using the conventional machine-shop and metal fabrication techniques such as drilling, cutting, smoothing, welding, bolting, polishing, sandblasting, and painting. It is shown with its design, functional aspects, and relationships of its components.

Figure 1 shows the isometric view of the portable manual rebar bender

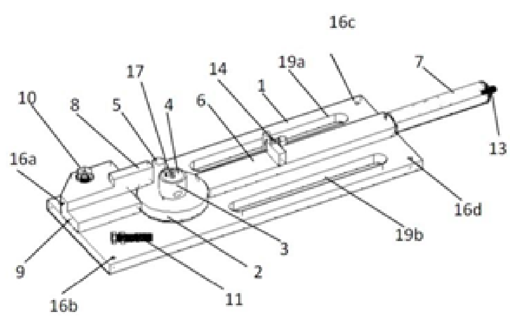

Fig 1. Isometric view of the portable manual rebar bender.

Figure 2 represents the top view of the portable manual rebar bender

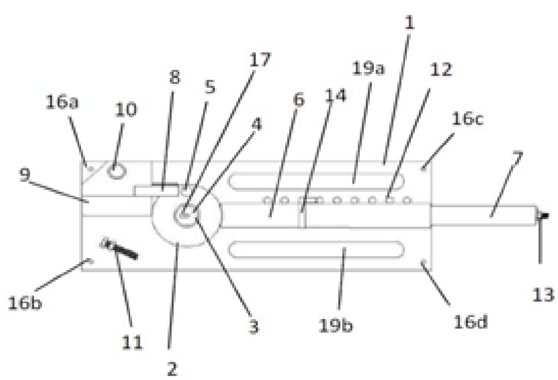

Fig 2. Top view of the portable manual rebar bender.

Figure 3 shows the front view of the portable manual rebar bender.

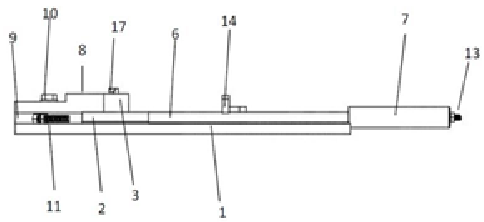

Fig 3. The front view of the portable manual rebar bender.

Figure 4 displays the right-side view of the portable manual rebar bender.

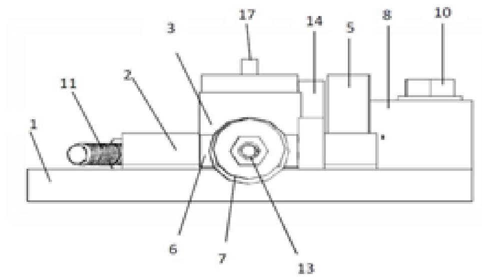

Fig 4. The right-side view of the portable manual rebar bender.

Figure 5 illustrates the left side view of the portable manual rebar bender.

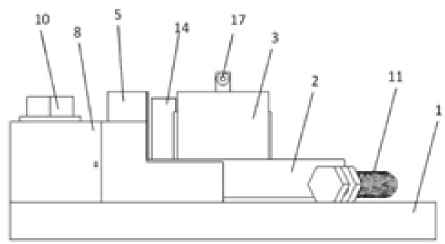

Fig 5. Left side view of the portable manual rebar bender.

Figure 6 shows the isometric view of the rotary steel plate.

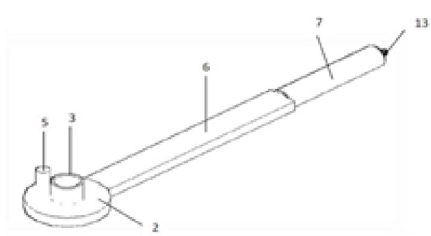

Fig 6. Isometric view of the rotary steel plate

Figure 7 displays the exploded isometric view of parts of the portable manual rebar bender

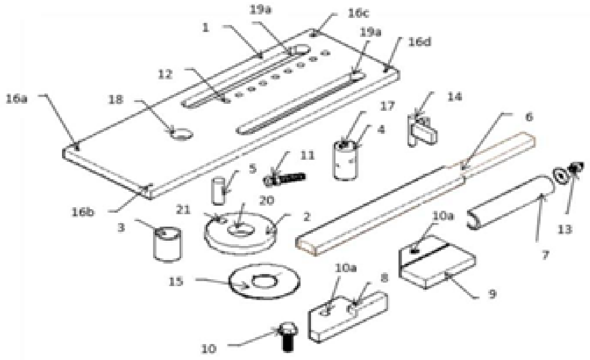

Fig 7. Exploded isometric view of parts of the portable manual rebar bender.

The method of making the device in the preferred embodiment and best mode will be described in detail. Referring to Figures 1, 2 and 7, first a suitable steel plate (typically 0.175m x 0.50m x 15mm) is cut for the steel base plate (1). A hole (18) slightly larger than 32mm diameter is drilled into the steel base plate (1), and the 32mm∅ high carbon steel pin (4) was welded in the hole, a grease nipple (17) was attached into the center top of the 32mm diameter high carbon steel pin (4) for lubrication, two holes (19a) and (19b) was drilled in the steel base plate (1) to serve as handle of the device, and another four holes (16a, 16b, 16c, and 16d), were drilled in the steel base plate for the log screw, nine measuring guide holes (12) were drilled in the steel base plate. A rebar guide plate (9) was welded on the upper left corner of the steel base plate (1) angle stopper (11) was also welded on the lower left side of the steel base plate (1) for measuring the desired angle of bend.

Referring now to Figures 2, 3, 4, 5, 6 and 7, the rotary steel plate (2) was fabricated typically using a 15mm thick steel plate and a hole (20) slightly larger than 40mm∅ was drilled in the center of rotary plate (2), and then the 40mm∅ steel bushing (3) was welded in the hole of the rotary steel plate (2), and another hole (21) slightly larger than 15mm∅ was drilled in the rotary plate (2) then the 15mm∅ high carbon steel pin (5) was welded on the hole (21) of the rotary steel plate (2), using a 15mm thick solid steel plate (typically 15mm x 40mm x 650mm in length) lever handle (6) was also welded on the side of the rotary base plate (2). After the fabrication of the steel base plate (1) and the rotary steel plate (2), the 40mm∅ steel bushing (3) that was welded on the rotary steel plate (2) was inserted into the 32mm∅ high carbon steel pin (4) with 100mm∅ x 6mm thick plain washer (15) place between the steel base plate (1) and the rotary steel plate (2), and then the G.I. pipe (7) was then attached at the end of the lever handle (6) was pinned with 6mm∅ bolt with nut and plain washer (13), the rebar adjustable guide (8) was bolted with 12mm∅ bolt with nut and washer (10) into the rebar guide plate (9) to pin the rotary steel plate (2), and the adjustable measuring guide (14) was put into the measuring hole(12).

Figure 8 displays the top view of the device with a piece of rebar inserted in the rebar guide and ready to bend.

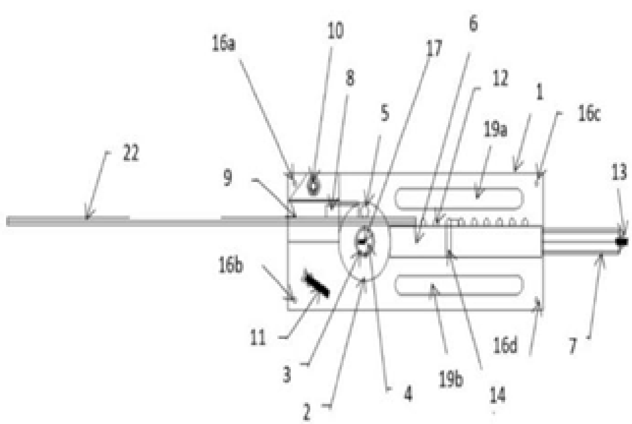

Fig 8. Top view of the device with a piece of rebar inserted in the rebar guide and ready to bend.

Referring to Figure 8, to use the device the pre-cut size of the rebar (22) was inserted at the rebar guide plate (9) and removable rebar adjustable guide (8) and pushed forward at the edge of the adjustable measuring guide (14) on top of the rotary steel plate (2) by the desired size of the stirrups/ties and when the necessary human force was exerted to bend the rebar (22), the base of the rebar adjustable guide (8) lingers parallel to the rebar guide plate (9) mounted on the upper left top of the steel base plate (1) and adjustably pinned a removable 12mm bolt with plain washer (10). It is the solid rebar guide plate (9) and the rebar adjustable guide (8) that holds the rebar when the necessary human force was exerted in a pivotal bending movement through the high carbon steel pin (5) that grips the rebar and the rotary steel plate (2), through the lever arm (6), with a G.I. pipe handle (7) attached to the end of the lever handle (6), was then rotated to achieve the ninety degrees angle of the rebar (22). The rotation of the rotary steel plate (2), the lever arm (6), and the G.I. pipe handle (7) were then repeated until the bending of the rebar was completed to produce a stirrup or tie.

The present device significantly improved the usefulness of the bending machine disclosed as prior arts of this study. This invention did rebar bending for reinforcement with negligible use of human force and without significantly increasing the cost of rebar production. Generally speaking, the present device is an improved portable manual rebar bender that significantly differs from the electric and hydraulic and portable manual rebar benders herein disclosed in the reference patent.

The invention materials were light but extremely formidable to resist the strength and pressure exerted by human force in bending the rebar. Unlike its reference patents herein disclosed, the invention was conveniently portable. This invention provided an effective and viable alternative for small contractors engaged in construction works to produce rebar efficiently with minimal expenses. It offered small construction firms the opportunity to acquire portable manual rebar benders affordable and marketable. Likewise, this invention provided a new and useful means of manufacturing a portable manual rebar bender and a method.

Although many other materials could be used to produce a manual rebar bender, the present technology, however, is mainly made of steel and metals that guarantee strength and durability, and lightness in weight. The components of the device were done through standard means of welding, bolting, and fabrication in the machine shop. The device was designed to address the need for rebar in places where construction works regardless of geographic conditions and terrains.

This device's primary purpose is to bend the concrete reinforcement bar commonly known as "Rebar." For these specifications and the preferred embodiment, the term "Rebar" will be used throughout.

3.2 Test Result of Portable Manual Rebar Bender in Terms of Capability, Accuracy and

Table 2 shows the result of the portable rebar bender's actual test in terms of bending time capability and time efficiency.

Table 2. Testing Result of the Portable Manual Rebar Bender According to BendingTime Capability and Time Efficiency

Stirrup or Tie	Trial in Second										Average Time
	Trial 1	Trial 2	Trial 3	Trial 4	Trial 5	Trial 6	Trial 7	Trial 8	Trial 9	Trial 10	
9mmØ	28	27	25	24	25	25	24	24	24	24	24.3
10mmØ	23	28	28	27	26	27	26	26	26	26	26.3
12mmØ	24	29	30	27	27	28	28	28	28	28	27.7

The result showed that after ten (10) trials, the Portable Manual Rebar Bender could finish9 mm stirrups at an average of 24.3 seconds, 10 mm at 26.3 seconds, and 12 mm stirrups 27.7 seconds. This means that the lesser the stirrup's size, the lesser is the time spent using the bender. As shown in the study, the number of seconds spent in bending using the present device, the 9 mm stirrup, had lesser than the two stirrups/ties (10 mm and 12 mm) as the sizes of the stirrup go up the number of seconds spent in bending increases likewise.

The result further showed that from seven (7) to ten (10) trials, the device's bending time efficiency stabilized to 24 seconds for 9 mm stirrup, 26 seconds for 10 mm, and 28 seconds for 12 mm stirrup. However, the time efficiency had been established to 24.3 for 9 mm, 26.3 for 10 mm, and 27. 7 for 12 mm. At first use of the machine, the operator cannot yet establish the constant time efficiency in finishing the stirrup/tie. This is probably because the operator has to master first the operation of the device. Once the operator mastered its operation, time to finish the stirrup according to the size desired.

The present device made the bending time shorter. The established average bending time was thirty seconds, established by Heavy Duty Bend Machine Electric 1” (#8) Rebar Bender, which can bend rebar up to 180 degrees. This is being sold in Walnut, California, in the United States of America. This Rebar Bender is being advertised online. This means that the Portable Manual Rebar Bender was faster than the Heavy Duty-Bend Machine Electric.

Table 3 shows the device’s accuracy test in 900 using the 7” length dimension of the stirrup and tie.

Table 3. Testing Result of the Portable Manual Rebar Bender According to Accuracy

Stirrup or Tie	90^0 Angle using 7 inches Length										Average
	Trial 1	Trial 2	Trial 3	Trial 4	Trial 5	Trial 6	Trial 7	Trial 8	Trial 9	Trial 10	
9mmØ	89.6	91	90	89.4	90	90	90	90	90	90	90
10mmØ	91	89.7	89.6	89.7	90	90	90	90	90	90	90
12mmØ	90	89.4	89.2	91.4	90	90	90	90	90	90	90

The result showed that after a series of ten trials, the device achieved an accurate angle bent of 90 degrees. In the first four trials (Trials 1- 4), the angle bent of stirrups differed and did not achieve the perfect 90-degree angle bent. However, after Trials 5 to 10, the device got a constant angle bending accuracy of 90 degrees depending upon the sizes desired (9 mm, 10 mm, and 12 mm).

The result showed that from five (5) to ten (10) trials, the bending accuracy was stabilized to 90 degrees. At first use of the machine, the operator cannot yet establish the bending accuracy in bending the stirrup/tie. This is probably because the operator has to master first the bending operation of the device. Once the operator mastered its operation, the bending accuracy of 90 degrees becomes constant.

Compared to this type’s bender machine, the present device bends stirrup/tie 90 degrees accurately and perpendicularly with a consistently desired dimension of stirrup/tie. The invention of Westward was described as Rebar Bender/Cutter, which can bend rebar at 90 and 180 degrees but was not consistent in the desired dimension of the stirrup/tie. This means that the Portable Manual Rebar Bender was accurate in bending 90 degrees and consistent in the desired dimension of stirrup/tie.

The following are the specifications of the portable manual rebar bender from the analysis of the actual test result in terms of timeliness and accuracy. Manually complete one stirrups 9mm∅ at an average of 24.3 seconds, 10mm∅ at an average of 26.3 seconds, and 12mm∅ at an average of 27.7 seconds. The capacity of about two stirrups or ties per minute or 120 stirrups per hour. Easy to carry to and from the job site, about 12 kg only, and bend from 0 - 120 degrees. Also, an adjustable handle gives a better option of leverage. When bending rebar, it is 15% easier than prior arts. The adjustable bending component gives you the best radius bend for all rebar up. The sturdy frame design comes ready for use right out of the box. A long no-slip handle grip ensures a good grip.

The functions of the fabricated tool were as follows: provide a usable portable rebar bender at the constructions sites; increase the performance of the steel man in preparing rebar, provide a conventional yet innovative portable rebar bender patterned from today’s modern hydraulic and electrical type rebar benders; provide the steel man with an easy and comfortable method of preparing rebar with less energy and cost; and, increase work performance and reliable geometric rebar sizes with less maintenance cost.

3.3 Acceptability of the Portable Manual Rebar Bender in terms of Design and Portability

Table 4 shows the result of the evaluation of the Portable Manual Rebar Bender’s acceptability in terms of design.

Table 4. Acceptability of the PortableManual Rebar Bender in Terms of Design

Design	Evaluators				Mean	Description
	Foreman	Steelman	Engineers	Industry		
1. The Manual rebar Bender posseses novelty	4.9	4.8	5	5	4.925	Very Acceptable
2.The parts and components of the device are properly fabricated to compliment on its function	4.6	4.6	4.8	4.8	4.7	Very Acceptable
3. The device is durable enough to endure stress during operation	4.7	4.6	4.8	4.8	4.725	Very Acceptable
4. The device produces a perpendicular bend of rebar	4.9	4.6	4.8	4.8	4.8	Very Acceptable
5. The device is equipped with measuring parts that suits to required sizes of rebar	4.9	4.6	4.8	4.8	4.8	Very Acceptable
6. The device could be adjusted to accommodate commercial sizes of bars from 9mmØ, 10mmØ and 12mmØ	4.8	4.6	4.8	4.8	4.8	Very Acceptable
7. The design provides safety to the user	4.9	4.8	4.8	4.6	4.6	Very Acceptable
8. The force applied by the hand in the handle meets its requirement for bending operation	4.7	4.6	4.8	4.8	4.8	Very Acceptable
9. The bender is easy to operate	4.9	4.8	4.8	4.8	4.8	Very Acceptable
10. The device is not expensive compared to the existing one	4.8	4.6	4.8	4.8	4.8	Very Acceptable
Mean	4.81	4.66	4.82	4.8	4.77	Very Acceptable

The result showed that the evaluators rated the Portable Manual Rebar Bender's acceptability in terms of design as "very acceptable" (M = 4.77). This means that the device possesses novelty, easy to operate, produces a perpendicular bend of rebar, safe for the user, and is equipped with measuring parts. The evaluators likewise agreed that the device had a design suitable for easy bending of the stirrup.

The result revealed that the Portable Manual Rebar Bender produced perpendicular rebar at a maximum of 120 degrees at 24.3 seconds for 9 mm, 26.3 seconds for 10 mm, and 27.7 seconds for 12 mm. The study's result was in contrast with the design of William Anthony Brian on March 3, 2005, entitled "Rebar Bender and Cutter with Patent No. 0044923 A1". This

Portable Manual Rebar Bender produced a perpendicular bend of rebar, safe for the user and equipped with measuring parts and consistent in the desired size of stirrup/tie. Whereas the design of William Anthony could bend and cut rebar of different angles and diameter, but could not produce a perpendicular and 90 degrees' stirrup/tie and was not consistent in the desired dimension of the stirrup/tie.

Table 5 shows the result of evaluating the acceptability of the Portable Manual Rebar Bender in terms of portability.

Table 5. Acceptability of the Portable Manual Rebar Bender in Terms ofPortability

Design	Evaluators				Mean	Description
	Foreman	Steelman	Engineers	Industry		
1. The device is provided with a casing for easy transport.	4.9	4.8	4.8	5	4.875	Very Acceptable
2.The weight of the device is just enough for easy manipulation.	4.9	4.8	4.8	4.6	4.775	Very Acceptable
3. Its size and shape is just enough to be held by one hand.	4.7	5	4.8	5	4.875	Very Acceptable
4. The device can be moved fron one place to another with person.	4.8	4.6	4.8	5	4.8	Very Acceptable
5. The device can be used in limited and complex areas in the part of the rebar subject for bending.	4.9	4.8	4.8	4.6	4.775	Very Acceptable
Mean	4.84	4.8	4.8	4.84	4.82	Very Acceptable

The result showed that the evaluators rated the Portable Manual Rebar Bender's acceptability in terms of design as "very acceptable" (M = 4.82). This means that the device is provided with a casing for easy transport, its size, and shape just enough to be held by one hand, and the device can be moved from one place to another with one person, and it can be used in the limited and complex area in the part of the rebar subject for bending.

The evaluators likewise agreed that the device could be moved from one place to another with one person and can be used in a limited and complex area in the part of the rebar subject for bending.

The result revealed that the Portable Manual Rebar Bender is provided with a casing for easy transport. Its size and shape just enough to be held by one hand and can be moved from one place to another with one person and can be used in the limited and complex area in the part of the rebar subject for bending.

The study's result was in contrast with the portability of the Hydraulic Rebar Bender Cutter, developed by Robert Frear published on June 19, 2012. This Portable Manual Rebar Bender was provided with a casing for easy transport, its size, and shape just enough to be held by one hand and can be moved from one place to another with one person and can be used in the limited and complex area in the part of the rebar subject for bending. In contrast, the Hydraulic Rebar Bender Cutter, developed by Robert Frear, a hydraulic rebar bender cutter attachment for the skid-steer loader. This could not be moved from one place to another by one person because of its extreme weight and awkwardness of rebar and the usually rough job site terrain; tabletop machines are not stable enough to efficiently perform. The trailer towed machines cannot access areas that skid steer loaders do either for job site space constraints or terrain features.

4 Conclusions

The design of the device meets the required standard of the industry based on the evaluation of experts from the engineering and construction industry. The accuracy of the device meets the required standard based on evaluation experts from the engineering and construction industry. The tool finishes one stirrup or ties at an average of 26.1 seconds during actual bending operation and is therefore highly acceptable to the experts. The safety of the device is highly accepted, meaning the portable manual rebar bender is safe to be used and manipulated in the construction site. In general, based on the results of the final evaluation conducted, the Portable Manual Rebar Bender is highly acceptable as evaluated by a group of experts and will be the basis of manufacturing suppliers to mass-produce the Portable Manual Rebar Bender. For civil engineering students, it is recommended that the portable manual rebar bender be used as a laboratory instructional gadget. For construction workers, it is recommended that the gadget be used in actual construction projects, for them to comment and revised if necessary for future development. For engineers and industry, it is recommended that the gadget be used actually by their steel man and determine the extent of its industrial application in terms of cost, portability and efficiency. For the researcher, it is recommended that this study be the basis of their future research about civil engineering work, especially rebar bender. It is further recommended that the gadget be provided with marks/labels for easy adjustment of stirrups/ties. It is also recommended that the 900 marks on the gadget must be indicated.

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