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Enhancing Urban Mobility and Safety: A Three-Storey Steel Car Park Proposal for Plaza Burgos, Guagua, Pampanga

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Abstract:

This study designed and analyzed a three-story steel car park structure for Plaza Burgos, Guagua, Pampanga. The primary focus was on safety, efficiency, and cost-effectiveness. The study was conducted in five phases: Data Gathering, Design and Analysis, Structural Analysis, Cost Analysis, and 3D Visualization, Rendering, and Animation using Enscape. AutoCAD was used for architectural design and STAAD Pro V8 for structural analysis and design. The framework consisted of strategically placed steel beams, columns, and trusses. The design adhered to the guidelines provided by the National Structural Code of the Philippines and the American Institute of Steel Construction. The selected steel beams demonstrated adequate strength and capacity to withstand applied loads. Reinforced concrete elements, such as pedestals and footings, enhanced stability and load-bearing capacity. Specialized connection plates and fittings ensured seamless integration of structural components. A comprehensive cost analysis estimated the total project cost, including structural building estimates, labor costs, and concrete work estimates. The proposed structure offers a practical solution to parking congestion in urban areas with limited space.

Keywords **—Plaza Burgos, Steel Car Park, Steel Beams, Columns, Trusses, Pedestal, Footings, Limited Space,Plaza Burgos, Parking Congestion, National Structural Code of the Philippines, American Institute of Steel Construction, STAAD Pro V8, AutoCAD, Enscape, Urban Areas**

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I. INTRODUCTION

Plaza Burgos in Guagua, Pampanga was a bustling hub of activity, home to entrepreneurs, students, government employees, and civilians who relied on transportation for their daily routines. However, the town faced significant traffic challenges due to a lack of adequate parking spaces, particularly in densely populated areas like the plaza. This scarcity resulted in vehicles occupying road shoulders and worsening traffic congestion. The growth of buildings and businesses in the area attracted more people but also led to inadequate parking spaces, causing illegal parking, traffic jams, and accidents. To address these challenges, a proposal for a three-story car park in Plaza Burgos aimed to provide a practical solution by alleviating traffic congestion and optimizing vertical space to offer secured parking facilities on every floor.

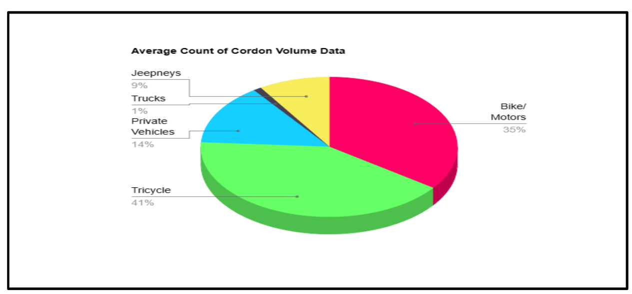


Figure 1: Average Count of Vehicles in 1 Hour

According to the vehicle count statistics, tricycles were the most common vehicles passing through

Plaza Burgos in one hour, followed by private vehicles, motorcycles, and bicycles.

The multi-story car park proposal aimed to enhance the town's accessibility and convenience for residents and visitors as Plaza Burgos continued to evolve as a center of industrial development.

A. Review of Related Literature and Studies

Illegal parking is a major traffic issue in cities, causing decreased traffic speeds, lost revenue, and accidents. Reducing illegal parking is crucial for increasing road capacity and improving mobility [4].

Illegal parking in the Philippines has become a significant issue for many metropolitan areas in huge, expanding cities. As a result, there could be problems with air pollution, traffic congestion, and public safety due to vehicle movement [5].

Three types of illegal parking violations in the Philippines can result in fines: Attended Illegal Parking (₱200-₱1,000), Unattended Illegal Parking (₱500-₱1,000), and Obstruction (₱150-₱1,000). Enforcers may use clamping as a measure to clear roads of illegally parked cars, and local and national government units have distinct rules and regulations regarding these violations [6].

Urban mobility in the Philippines involves private and public transportation, addressing traffic congestion and pollution. The DPWH and National Building Code provide parking criteria and requirements. Multi-level parking systems are popular due to commercial and industrial expansion, with steel-concrete composite frames reducing costs by 30-50% [7].

Using steel structures as a supporting frame for a five-story parking garage can reduce the load transmitted to the foundation by up to 30%, resulting in cost savings. The load from steel structures is nearly 2.5 times less than that from reinforced concrete structures [8].

Passive fire prevention is common in steel parking garages. The suggested plan was compared to a method effective in bare steel parking lots. Steel constructions are safer than concrete ones due to lower fire load density and better vehicle performance [9].

Steel and light steel frames increase a structure's sustainability due to their recyclability and reusability. They have several benefits over other materials, including lower cost, modular components, improved quality control, and reduced weight. However, steel conducts heat poorly, requiring continuous thermal insulation [10].

Steel Composite structures are more expensive to manufacture and install, but their prefabricated design reduces building time by 27-30%, potentially saving on overhead and material costs [11].

STAAD Pro is an efficient design software for analyzing and designing multistorey structures up to 10 floors. It is adaptable and suitable for designing various structures using different materials. Structural analysis using STAAD Pro involves applying mathematical and physical principles to examine how structures function [12].

B. Statement of the Problem

The study aimed to address parking issues in Plaza Burgos, Guagua, Pampanga, where limited parking spaces cause congestion and safety concerns. A three-story steel car park was designed to alleviate these issues, saving space and reducing traffic, and enhancing accessibility and convenience for visitors and residents.

C. Objectives

General objectives:

Developed a three-story steel parking structure for the establishments for Plaza Burgos, Guagua, Pampanga.

Specific Objectives

The research intended to:

1. Offered an appropriate safe parking space design for drivers around the Plaza Burgos, Guagua, Pampanga;
2. Drafted a feasible section of beams, columns, and footings; and
3. Proposed an approximate estimation of the structure.

D. Scope and Limitations

The study proposes a three-story steel car park for Plaza Burgos in Guagua, Pampanga, with 73 parking slots and an area of 934.97 square meters. The car park is designed to be approximately 22.31 feet tall above ground, with each level being 9.19 feet high. The structural plan includes the design and analysis of beams, columns, and other load-bearing components. The car park meets the minimum parking space requirements of the

National Building Code (NBC) and is intended to be built at 284 Feeder Road, Sto. Cristo Guagua, Pampanga.

II. METHODS

The research study was conducted in five phases: Phase 1 - Data Gathering, Phase 2 - Design and Analysis, Phase 3 - Structural Analysis, Phase 4 - Cost Analysis and Bill of Quantities, and Phase 5 - 3D Visualization, Rendering and Animation with Enscape.

2.1 Phase 1: Data Gathering

Stage 1: Traffic Analysis using level of service (transportation)
Stage 2: Establishing the attributes and suitability of the selected parking area through the utilization of the Site and Location Investigation
Stage 3: Gathering the necessary data to accurately determine the number of parking spaces needed for the parking lot

2.2 Phase 2: Design and Analysis

Analyzed and designing vertical parking was the second stage. The land use and structure design were the main topics of this section.
Stage 1: Analyzed different types of loads as per NSCP 2015.
Load Analysis

The following loadings, including dead loads, live loads, and environmental loads, were taken into account in the designed parking structureaccording to NSCP 2015.

Seismic Load Parameters according to NSCP 2015
Seismic source type: Type A
Soil profile type: SD
Seismic zone factor: Zone 4
Occupancy Category: III
Reduction Factor: 0.4
Near source factor (Na): 1.0
Near Source Factor (Nv): 1.0
Seismic coefficient (Ca): 0.44Na
Seismic coefficient (Cv): 0.64Nv
Importance factor:1
Seismic numerical coefficient: 8

Figure 3: Nearest Active Fault according to Fault Finder from PHILVOLCS

Stage 2: Designed the architectural plan using AUTOCAD
Stage 3: Designed structural framing plan using STAAD

2.3 Phase 3: Structural Analysis

The researchers used STAAD to design a structural frame for a parking structure. The design included a reinforced concrete pedestal and footing, steel columns, and horizontal steel beams and girders. The National Structural Code of the Philippines (NSCP 2015) and the American Institute of Steel Construction (AISC) were used as guidelines for the analysis and specifications. Both automatic and manual methods were used to complete the standard specs and computations.

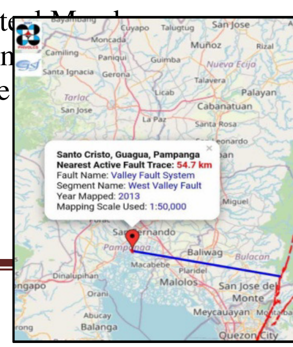
Structural Period (T)Method A
T = Ct(hn)3/4
Where:
hn = total height of the structure
Ct = 0.0853 for steel moment resisting frames
Ct = 0.0732 for Reinforced Concrete
Ct = 0.0488 for all other building
Ct = can also be taken as 0.0743/√Ac
Ac = Ae [0.2+Dehn2]

Design Base Shear
Vact = (CvI/RT)(W)
Vmax = (2.5CaI/R) (W)
Vmin = 0.11CaIW
Note for Seismic Zone 4: V= (0.8ZNvI/R) (W)
Distribution of Loads

$$Fx = \frac{(V - F_t)Wxhx}{\Sigma Wihi} V = Ft + \Sigma_1^n = F_1\ F_t = 0.07TV$$

Note: Ft = 0 if T < 0.7 seconds

Properties of St
The steel men ory parking structure were W Shapes



Dimensions and Properties for columns, beams, and girders, and American Standard Dimensions and Properties for floor joists. Pipe Dimensions and Properties were used for the bracing design. The LRFD specification was followed, considering all code provisions.

Steel Beams

The design of a steel beam involved calculating the factored service load moment (Mu), plastic modulus (Zx), and checking the compactness of the web and flange cross-section. The shear, flexure, and deflection were also checked to ensure the beam's safety. For steel columns, the ultimate loads (Pu) were determined, followed by checking the slenderness ratio and generating column lengths and widths based on AISC specifications. The critical buckling stress was calculated to determine if the design capacity is safe.

Base Plate and Anchor Bolts

The design process ensured the base plate of a steel column securely transferred loads to the foundation. The researchers used a phi factor of 0.65 to determine the strength of the concrete-to-column connection, and calculated the thickness of the base plate and bearing pressure. Anchor bolts were designed to meet safety and regulatory standards, with a comparison made between actual and tensile capacity to ensure safety.

TABLE I
PROPERTIES OF STEEL MEMBERS FORMULAS/ EQUATIONS

Isolated Rectangular Footing	
Description	Formula
Area of the Footing	$\frac{Pu}{Qe}$
Effective Soil Pressure	$Qe = Qa - ychc - yshs$
Check for One-way Shear	$0.17(1)\sqrt{f'cbwd} = qubw(c-d)$
Check for Two Way Shear/ Punching Shear	$qu(BL - bo^2) = 0.75(BL - bo^2)d$
Area of Steel	$As = pb_w d$
# of Steel in Both Directions	As/Ab
Pedestal	
Description	Formula
Area of Steel	$As = \frac{As(actual)}{A(actual)}$
Adequacy of the Pedestal	$Pu = \emptyset 0.85A(actual)[0.85f'c(1 - pg(actual)) + pg(actual)Fy]$ $S = 16d_b$ $S = 48d_t$ $(S = Smallest\ size\ of\ column)$
Steel Beams	
Description	Formula
Compactness of steel section	$Mp = \emptyset bZxFy$ $Mu \le Mp, Mu = Mp$ $Zx\ (ln3) = \frac{Mu}{\emptyset bFy}$
Flange	$\lambda \le \lambda_p$ $\frac{bf}{2tf} \le 0.38\sqrt{\frac{E}{Fy}}$ $(compact)$
Web	$\lambda \le \lambda_p$ $\frac{h}{tw} \le 3.76\sqrt{\frac{E}{Fy}}$ $(compact)$
Flexure	$Mp = \emptyset bZxFy > Mp = \emptyset bZxFy$
Shear	$Vu(cap) = \emptyset v0.60FyAwCr > Vu(max)$ $\therefore safe\ in\ shear$
Deflection	$\delta allow = \frac{L}{360} > \delta act = \frac{5\omega L4}{384EI}$ $(Therefore, safe\ in\ deflection)$
Steel Columns	
Description	Formula
Long Column	$\frac{KL}{r} = Cc = 4.71\sqrt{\frac{E}{Fy}}$
Critical Buckling Stress	$Fe = \frac{\pi^2 E}{\left(\frac{kl}{r}\right)^2}$ $F_{cr} = 0.877Fe$ $F_{cr} = 0.65^{\frac{Fy}{Fe}}(Fy)$
Design Capacity	$P_{design} = \emptyset FrcAg > Pu \therefore Safe$
Base Plate	
Description	Formula
Normal Bearing Strength	$\emptyset = 0.65\ (bearing)$ $Pu = \emptyset\ (0.85\ f'c\ A1)\sqrt{\frac{A2}{A1}} \le 1.7f'cAl$
Thickness of Base Plate	$treq. = e\sqrt{\frac{2Pu}{0.90fyBN}}$
Actual Bearing Pressure	$fp = \frac{Column\ load}{Column\ Base\ plate}$
Anchor Bolts	
Description	Formula
Bolt Tensile Capacity	$Tu(actul) = \frac{Pu}{N} > Tu(cap) = 0.75\emptyset F_u A_g$ $(safe)$
Hook Length	$Lh = \frac{Tu}{\frac{2}{0.7f'cdb}}$
Length of the Bar	$L = 3.6 + 12(d)$
Minimum Edge Distance	$e = 5d > 4\ in$

Pedestal

The design of a pedestal, a short column, involved considering the interaction between components for overall stability and safety. The researchers followed NSCP 422.4.22 to design the pedestal, determining the maximum axial capacity, balance condition capacity, and eccentrically loaded section capacity due to applied load. They also checked compression controlled capacity and maximum shear.

Isolated Footing (Square)

The design of a rectangular footing involved determining the dimensions and checking for one-way and two-way shear. The researchers then calculated the steel requirements, including the number of bars, and checked the minimum reinforcement area across the column interface and footing.

2.4 Phase 4: Cost Analysis and Bill of Quantities

4.1 Cost Analysis

Researchers manually calculated the cost estimate for a parking facility, determined the optimal steel and reinforcement quantities, and calculated the total volume of steel and concrete.

4.2 Bill of Quantities

The Bill of Quantities (BOQ) provided precise measurements and specifications for the parking facility, ensuring a clear understanding of the work involved and facilitating accurate cost estimation and project management.

2.5 Phase 5: 3D Visualization, Rendering and Animation with Enscape

The researchers used AutoCAD and STAAD to design the steel car park, then imported the 3D models into Enscape for interactive visualizations. This allowed viewers to walkthrough and explore the structure, creating a dynamic presentation of the proposed three-storey steel car park.

III. RESULTS AND DISCUSSION

The key findings of the study are detailed in this chapter. The data provided represents the responsible evaluation and design efforts of the researchers, as per the guidelines set forth in NSCP 2015.

3.1 Traffic Analysis using level of service (Transportation)

TABLE II

LEGEND OF LEVEL OF SERVICE AND CONDITION

LEVEL OF SERVICE (LOS)	CONDITON	VCR
A	Free Flow	0.00 – 0.19
B	Reasonably free flow	0.20 – 0.44
C	Stable flow	0.45 – 0.69
D	Approaching unstable flow	0.70 – 0.84
E	Unstable flow	0.85 – 1.00
F	Forced or breakdown flow	> 1.00

TIME		MON	TUE	WED	THURS	FRI	SAT	SUN
6:00 AM – 8:00 AM		D	D	F	D	F	C	C
1:00 PM – 3:00 PM		F	F	E	E	E	E	F
5:00 PM – 7:00 PM		E	E	E	E	E	D	F

TABLE III
RESULTS OF THE LEVEL OF SERVICE AND CONDITION

Table 2 categorized traffic flow into six levels based on congestion, from free flow to extremely high flow. Table 3 showed a breakdown of traffic conditions during specific time periods, categorizing the level of service into six levels from A to F. The table covers three time periods on each day of the week, showing that weekdays have worse conditions than weekends, with the worst conditions on Monday, Tuesday, and Sunday.

Table IV
Based on National Building Code

Type of occupancy	Area	Parking Requirements	Slots
Shopping Centers	1,965.75 [m2]	$1[slot]/100[m^2]$	20
Markets	3,485.29 [m2]	$1[slot]/150[m^2]$	23
Fast food outlets	445.54 [m2]	$1[slot]/30[m^2]$	15
Office Building	1,725.97 [m2]	$1[slot]/125[m^2]$	14
Total 73 [slots]			

The table provided the establishments around Plaza Burgos, Guagua, Pampanga. An approximate 30 establishments were analyzed to estimate the number of required parking slots. The establishments include a shopping center, markets, fast-food outlets, and office buildings. The table shows the total area required for each establishment and the corresponding number of parking slots needed. The total number of parking slots needed to alleviate traffic conditions is 73.

Design and Analysis

3.2 Designed the architectural plan using AUTOCAD

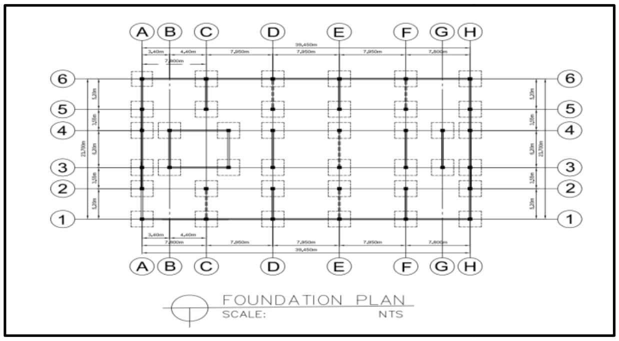
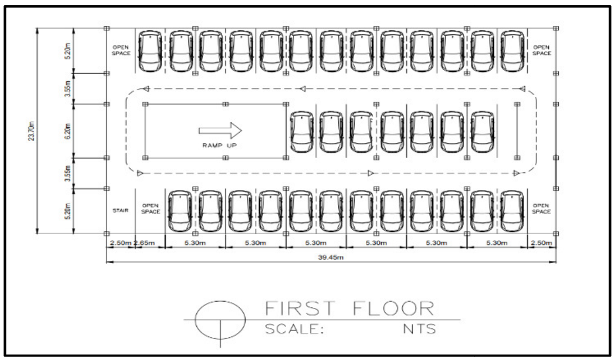


Figure 4: Foundation Plan



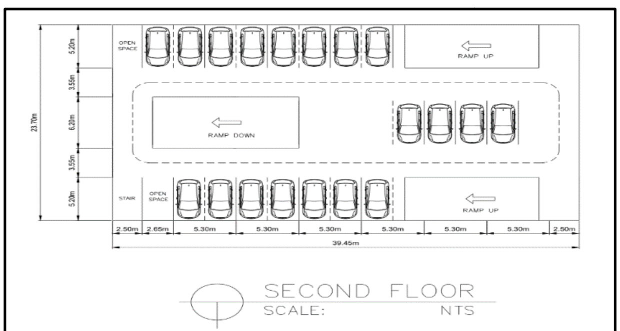


Figure 6: Floor Plan for Second Floor

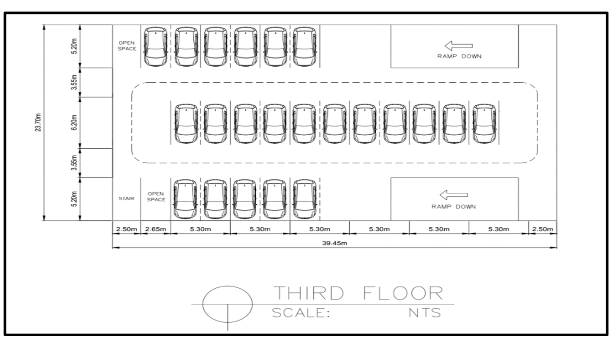


Figure 7: Floor Plan for Third Floor

Researchers used AutoCAD to create detailed architectural plans and drawings for a three-story steel car park in Plaza Burgos, including floor plans, foundation plans, elevations, sections, and other details.

3.3 Designed structural framing plan using STAAD

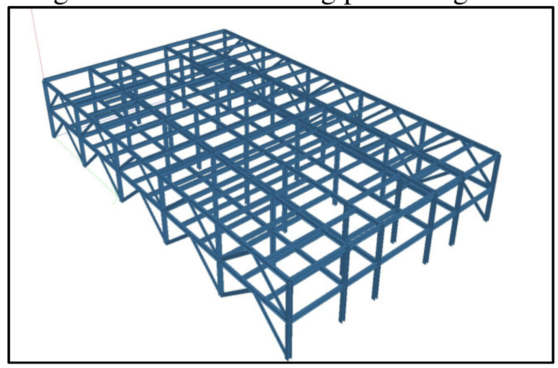


Figure 8: Rendered View of the Structural Framing Plan

The researchers used STAAD.Pro software for the structural analysis and design of the proposed car park. They input design parameters and properties into the software to analyzed loads, stresses, and other structural considerations, ensuring the structure met safety standards and requirements.

Structural Analysis

3.4 Properties of Steel Members

Steel Beams

Design of Beam Members

Table V
W14X48 PHYSICAL PROPERTIES

Dimension	Value
Depth (D)	13.8in or 350.52mm
Base of Flange (bf)	8.03in or 203.962mm
Thickness of Web (tf)	0.595in or 15.113mm
Web Thickness (tw)	0.34in or 8.636mm
Fillet Radius (R)	0.595in or 15.113mm

Table VI
FINDINGS FOR BEAM W14X48

CONNECTION	0.8 (FIXED) < 1 [OK!]
FLANGE	6.748 < 10.791 (COMPACT)
WEB	33.594 < 106.777 (COMPACT)
kL/Ry	54.664 <300 (GOVERN)
Mu > Mact	286.755 kN-m > 263.432 kN-m

The design of the W14x48 beam considers a connection factor of 0.8, indicating a fixed connection. The flange and web are both compact, with values less than the limits. Lateral-torsional buckling governs the design, with a value of 99.06. The ultimate moment capacity (Mu) of 286.755 kN-m exceeds the actual moment capacity (Mact) of

263.41 kN-m, ensuring the beam can withstand the applied loads.

Design of Girder Members

TABLE VII
W12X45 PHYSICAL PROPERTIES

Dimension	Value
Depth (D)	12.1in or 307.34mm
Base of Flange (bf)	8.05in or 204.47mm
Thickness of Web (tf)	0.575in or 14.605mm
Web Thickness (tw)	0.335in or 8.509mm
Fillet Radius (R)	0.505in or 12.827mm

TABLE VIII
FINDINGS FOR GIRDER W12X45

COMBINED COMPRESSION & BENDING CAPACITY (AISC 360-O5 HI)	0.709 < 1.0 (ADEQUATE)
KL/R (MAX)	124.942 < 300 (ADEQUATE)
Mcz = Mn/Ωb	130.519 kN-m < 156.232 (AISC 360-05 CHAP. E) (ADEQUATE)
Amax < L/240	(ADEQUATE)

The W12x45 girder is adequate for combined compression and bending, with a capacity of 0.709, less than the limit of 1.0. The maximum KL/r ratio is 124.942, less than the limit of 300, and the flexural strength Mcz is 130.519 kN-m, less than the AISC 360-05 limit. The maximum deflection is also within the acceptable limit.

3.4.2 Steel Columns

Design of Column Members

Table IX
W12x65 Physical Properties

Dimension	Value
Depth (D)	12.1in or 307.34mm
Base of Flange (bf)	12in or 304.8mm
Thickness of Web (tf)	0.605in or 15.367mm
Web Thickness (tw)	0.39in or 9.906mm
Fillet Radius (R)	0.595in or 15.113mm

TABLE X
FINDINGS FOR COLUMN W12X65

COMBINED COMPRESSION & BENDING CAPACITY (AISC 360-O5 HI)	0.454 < 1.0 (ADEQUATE)
KL/R (MAX)	39.132 < 200 (ADEQUATE)
Pc =Rn/Ωc	372.123 < 1688.34 kN (AISC 360-05 CHAP. E) (ADEQUATE)
Mcz = Mn/Ωb	105.05 kN-m < 235.565 kN-m (AISC 360-05 CHAP. E) (ADEQUATE)
Amax < L/240	(ADEQUATE)

The W12x65 column design is adequate, with a combined compression and bending capacity of 0.454, less than the 1.0 limit. The maximum KL/r ratio is 39.132, much less than the limit of 200. The compressive strength Pc of 372.123 kN is less than the AISC 360-05 limit of 1688.34 kN, and the flexural strength Mcz of 105.05 kN-m is less than the AISC 360-05 limit of 235.565 kN-m. The maximum deflection is also within the acceptable limit of L/240.

Design of Truss Members

TABLE XI
W10X12 PHYSICAL PROPERTIES

Dimension	Value
Depth (D)	9.87in or 250.698mm
Base of Flange (bf)	3.96in or 100.584mm
Thickness of Web (tf)	0.21in or 5.334mm
Web Thickness (tw)	0.19in or 4.826mm
Fillet Radius (R)	0.3in or 7.62mm

TABLE XII
FINDINGS FOR TRUSS W10X12

		at x (m) = 0	due to live load	
LOAD COMBINATION	1.40D L	1.2D+1.6 LL	1.2D+1 .0E+0. 5L	1.0D+0.714E Q
MOMENT Mu (kN-m)	0	-0.62	0.101	0.264
at x (m)	0	-0.217	-0.062	0.035
SHEAR Vu (kN) at x (m)	0 0	2.22 0.363	2.14 0.292	2.10 0.286
Axial Load (kN)	0	107.535	58.53	40.427
REQ. FLEXURAL STRENGTH (Mu) (kN-M)		-0.62	at x = 0 (m)	

The Load and Resistance Factor Design method was used to determine the most effective load combination for the Steel Car Park. The combination 1.2DL + 1.6LL was found to have the maximum moment (-0.62 kN-m) and shear (-0.217 kN-m). This combination should be considered in designing for structural integrity and safety. The maximum moment of -0.62 kN-m is crucial in ensuring the design is structurally sufficient. Additionally, the shear strength of 3.213 kN established using STAAD is more than adequate compared to the maximum shear, indicating the design suffices in terms of shear strength.

Base Plate and Anchor Bolts

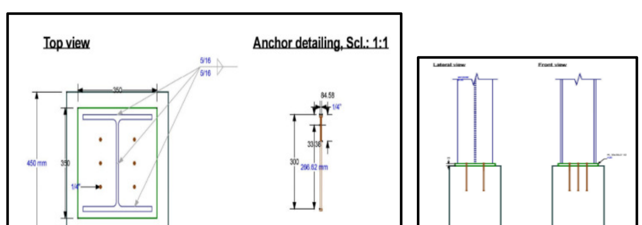


Figure 9: Design of Base Plate and Anchor Detailing

The STAAD Pro software was used to design the base plate and anchor bolts of the structure. The base plate had a cross-section of

350mmx350mmx25mm with 3 bolts on each side, and the steel bolts were 300mm long with a 25mm diameter. The software generated a capacity-to-load ratio of 0.46, which is considered safe since it is less than 1.

3.4.4 Pedestal

Design Parameters:

h = 450 mm	Main bars = 25 mm ⌀
f'c = 27.5 MPa	Lateral bars = 10 mm ⌀
fy = 415 MPa	Muz = 105.05 kN-m
fck = 25 MPa	Axial Force = 372.123 kN

Using SP - 16 Chart 32 Compression with Bending - Rectangular Section - Reinforcement Distributed Equally on Two Sides

TABLE XIII
CHECK STEEL BARS

Pu / fckbd	0.09
Mu / fckbd^2	0.065
P / fck	0.04
P	1%
Ast = pbd	2025mm2
N = Ast/Ab	4.12 ~ 5 - 25mm ⌀ R.S.B
	@ (p. 41) IS 456-2000 ⌀ Lat ties > 1/4 20mm ∴ 10mm ⌀ Lat ties
Spacing	1. D = 450mm 2. 16db = 16(25) = 400mm 3. 300mm (govern)

Table 13 showed the checking the adequacy of the steel bars used in the truss. The ratio of axial load to concrete strength and cross-sectional area is 0.09. The ratio of bending moment to concrete strength and cross-sectional area is 0.065. The ratio of axial load to concrete strength is 0.04. The reinforcement ratio is 1%. The required steel reinforcement area 2025 mm². The recommended number and size of reinforcement bars, 4.12 ≈ 5 - 25 mm ⌀ R.S.B. The requirements for lateral ties, with a diameter of 10 mm and a spacing of 300 mm were also specified.

Isolated Footing (Square)

TABLE XIV
PARAMETERS OF THE ISOLATED SQUARE FOOTING

Concrete Strength, f'c	27.5 MPa
Rebar Yield Strength, fy	414 MPa
Length, L	2.5m
Width, B	2.5m
Footing Thickness, t	0.5m
Depth, d	387.5mm
Axial Force	861.533 kN
Qu	861.533/2.52=137.845 kN/m2

Wide Beam:

TABLE XV
CHECK ONE-WAY SHEAR

Vu	quxB	217.966 kN
ΦVc	Φ017 $\lambda\sqrt{f'c}$ bd	647.721 kN
SAFE!		

Punching Shear:

TABLE XVI
CHECK TWO-WAY SHEAR

Vu	quxBo	777.537 kN
ΦVc	Φ017 $\lambda\sqrt{f'c}$ bd	1803.46 kN
SAFE!		

Reinforcement Steel Bars:

TABLE XVII
CHECK FLEXURAL REINFORCEMENT

dmoment	412.5 mm
Mu	177.931 kN
Rn	0.4648 MPa
ρ	0.001346
ρmin	0.00338
As	3485.625 mm2
N	7.1 ≈ 8 - 25mm ⌀(bothways)

Table 14-16 showed the structural design analysis of an isolated square footing with specific parameters. The footing dimensions include a length (L) and width (B) of 2.5m, a thickness (t) of 0.5m, and a depth (d) of 387.5mm. The concrete strength (f'c) is 27.5 MPa, and the rebar yield strength (fy) is 414 MPa. The footing is designed to support an axial force of 861.533 kN. The design checks for one-way shear, with a factored shear force (Vu) of 217.966 kN and a nominal shear capacity (ΦVc) of 647.721 kN, confirming safety against one-way shear. For two-way shear, the factored shear force (Vu) is 777.537 kN, and the nominal shear capacity (ΦVc) is 1803.46 kN, indicating safety against two-way shear. The flexural reinforcement analysis determines a required reinforcement area (As) of 3485.625mm2, corresponding to 8 - 25mm diameter bars in each direction. Overall, the isolated square footing was designed to meet structural safety standards and effectively support the applied loads.

3.5 Cost Analysis and Bill of Quantities

Structural Building Estimates

TABLE XVIII
STRUCTURAL BUILDING ESTIMATES

No.	Description	Quant	Unit	Unit Price	Total

		ity			
1	W14x48 structural steel beam was the wide flange used as the main beam in the structure.	14 4	6m	20, 509	Z2, 953, 296
2	W12x65 steel beam was the wide flange used as the girder.	44	6m	28, 954	1, 273, 976
3	W12x65 steel beam was the wide flange used as the column.	69	6m	19, 227	1, 326, 663
4	W10x12 steel beams was the wide flange used for the truss member.	37	6m	6, 327	234, 099
5	20mm A36 Anchor Bolts	26 4	piece	324	85, 536
6	3/4'' A325N Bolts	31	100 piece s	12, 978.51	402, 334
7	A36 base plate with dimensions of 350x350x25 mm was used.	44	piece	2, 370	104, 280
8	25mm dia. Bars was used for concrete pedestal and footing.	1, 06 7	piece	642	685,014
Sub Total					7, 065, 198
Labor					2, 826, 079.2
Total					9, 891, 277.2

The table listed materials and their corresponding quantities, unit prices, and total costs for the proposed steel car park. The materials included structural steel beams of different sizes and weights, anchor bolts, bolts, base plates, and bars. The total cost for the structural building estimates was ₱7,065,198, with an additional ₱2,826,079.2 in labor costs, resulting in a total cost of ₱9,891,277.2 for this phase of the construction project.

TABLE XIX
CONCRETE WORK ESTIMATES

No.	Description	Quantit y	Un it	Unit Price	Total
1	Cement was used in the construction of the footing and concrete pedestal.	1, 374	40 kg	220	302, 280
2	Sand was used in the construction of the footing and concrete pedestal.	76.324	cu. m	1350	103, 037.4
3	Gravel, ¾ was used in the construction of the footing and concrete pedestal.	152.64 7	cu. m	1210	184,702.87
Sub Total					590,020.27
Labor					236,008.108
Total					826,028.378

The table of Concrete Work Estimates included materials and their costs for the construction project. The Cement, Sand, and Gravel items had total costs of 302,280, 103,037.41, and 184,702.87, respectively. The sub-total is 590,020.27, with labor costs adding 236,008.108, resulting in a total cost of 826,028.378.

IV. CONCLUSIONS AND RECOMMENDATION

The researchers used AutoCAD for architectural design and STAAD Pro V8 software for structural analysis and design to ensure the safety and quality of a proposed three-story steel car park in Plaza Burgos. The integration of AutoCAD, STAAD, and Enscape in car park design showcases the importance of modern software in civil and structural engineering, enhancing the design and planning of infrastructure projects through detailed architectural plans, structural analysis, and realistic visualizations. The framework of the structure consists of strategically placed steel beams, including W14x48, W12x65, W12x45, and W10x12, used in girders, beams, columns, and trusses to provide structural strength. The analysis showed that the selected steel beams can support the loads and meet the design requirements, ensuring the structure's overall stability and durability. The pedestal and footing in reinforced concrete have also been proven safe for the required loads. The total cost of the steel car park is estimated to be 10,717,305.578, including structural building estimates, labor costs, and concrete work estimates. This proposed car park is a vital infrastructure for efficient car parking and traffic management, optimizing vertical parking structures to maximize the use of available land and enhance urban mobility in densely populated urban centers.

The study recommends exploring additional lots for designated parking areas. Additionally, the design of the structure's slab should prioritize load carrying capacity and durability. Furthermore, it is recommended to find alternative suppliers in the nearby vicinity for the construction of the parking facility. It is encouraged that engineers and designers continue to explore the full capabilities of AutoCAD, STAAD, and other similar software solutions to innovate and enhance possibilities within the built environment.

REFERENCES

[1]A. Singh, "Problem of parking in urban areas and their possible solutions| Countercurrents," Countercurrents, Jul. 14, 2021. [Online]. Available: https://countercurrents.org/2021/07/problem-of-parking-in-urban-areas-and- their- possible-solutions/

[2]J. Sethy, "Multi level car parking," ResearchGate, Oct. 2020, doi: 10.13140/RG.2.2.34984.19206.

[3]"Official website of Guagua, Pampanga," Official Website of Guagua, Pampanga, May 14, 2021. https://www.guagua.gov.ph/

[4]T. M. T. Truong and H. Friedrich, "Legalizing the illegal parking, a solution for parking scarcity in developing countries," Transportation Research Procedia, vol. 25, pp. 4950–4965, Jan. 2017, doi: 10.1016/j.trpro.2017.05.374.

[5]C. Casuat, "ILL-Park: A Deep Learning approach of Illegal Parking Detection," Dec. 15, 2020. http://tjct.isujournals.ph/index.php/tjct/article/view/2

[6] E. Lee, "What are the consequences of illegal parking in the Philippines?," AutoDeal, Nov. 29, 2021. https://www.autodeal.com.ph/articles/car- features/what-are-consequences-illegal-parking-in-philippines

[7] Panchal, "Design and Analysis of Multilevel Car Parking In JUIT," Jaypee University of Information Technology, vol. 1. 2016. http://www.ir.juit.ac.in:8080/jspui/bitstream/.pdf

[8] T. Simankina, V. Lukinov, and Д. М. Давыдов, "Optimization of intercept parking lots," E3S Web of Conferences, vol. 217, p. 03010, Jan. 2020, doi: 10.1051/e3sconf/202021703010.

[9] D. Mondal, "MULTI LEVEL STEEL CAR PARKING A smart choice for eliminating traffic congestion," ResearchGate, Oct. 2016, doi: 10.13140/RG.2.2.21185.76646

[10] B. J. Choi, "Investigation of Field Construction and Economic Efficiency for Steel Plate-Concrete Structures with Application of Parking Building," www.academia.edu, Oct. 2021, [Online]. Available: https://www.academia.edu/55954119

[11] B. L. Rajput, "Time and cost comparison of construction of RCC, steel and composite structure building," Jun. 26, 2014. https://papers.ssrn.com/sol3/papers.cfm?abstract_id=2459409

[12] M. Mishra, S. Sri, and P. Das, "Static and Dynamic Analysis of Multistoried Structure by Staad Pro," ResearchGate, [Online]. Available: https://www.researchgate.net/publication/342747426_Static_and_Dynamic_Anal ysis_of_Multistoried_Structure_by_Staad_Pro

