Determination of a sustainable concrete floor and ramp for automotive lube bay shed in Nigeria

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Abstract.
Structural construction of concrete floors and ramps by unskillful personnel that allows undesirable substances that affect the quality of concrete, inappropriate concrete mix that determines the right blend for compressive strength, workability, durability, and chemical resistance have been identified as the reason for collapse of structures. The results show that most failures can be attributed to poor design and workmanship that could have been avoided by careful attention to the factors that makes a quality installation. This project is out to select concrete grade based on functional strength specification and material availability, not only on mix ratio, and in tandem with the technological manufacture or repair of automobiles, and for practical experience. The selection of functional concrete grade results to better mass concreting, compaction, curing and process optimization.

Keywords: quality concrete, uniform mix, mix design, workability, functional concrete grades

1 Introduction
In the early century, wood flooring was constantly used, but today concrete flooring is largely used due to its versatility, reliability, sustainability, and provides a lasting covering effect on the floor [1]. The Ramp is an inclined surface that tilts from one level to another [2]. Flooring and Ramp a step in the designing and construction of an automobile lube bay service center is poised to make structures that will go to use seamlessly without defects, slips/trips/falls, loss of business and damage to quality. Therefore, it is pertinent to examine the solid ground surface and ramps procedures and arrives at the best concrete flooring and ramp for the construction of the lube bay shed framework for optimum performance and increased life span, providing a standard concrete parking lot, pit and shed where inspection, servicing and repairing of automobiles can be carried out [3]. According to flooring professional’s David Kent Ballast [4] states the choice of flooring material consider the limiting factor for the design which include the properties, processes, types, availability, cost, endurance, insulation, comfort, and cleaning effort for concrete flooring and ramp construction are used more than any other man-made flooring material to resist deformation, to drain well, to support repair and maintenance requirement for resilient, durability and reliability to slip, trip and fall injuries [5]. The consequences associated with accidental falls, and prevention with the type of flooring and underlying material used, explain the need to select flooring according to purpose [6]. According to NBRRI, 2011 [7] structure failure occurs frequently during the construction period than in service, capital-intensive venture, and social implications when it fails. The use of concrete flooring, the causes of failures such as environmental exposure, preparation of quality concrete, product mix selection should be observed and prevented to optimize the structures [8]. Concrete flooring and ramp production and management, untalented and inexperienced persons should not be allowed to manage the process. Unfortunately, this is the practice in Nigeria have not been widely followed. Hence, this study look into the determination of a sustainable concrete floor and ramp for automotive lube bay shed in Nigeria

2 Experimental Procedures:
2.1 Concrete making
1. Select concrete material of good quality consisting of sand, granite, binding agent, water and air.
2. Determine the types of concrete
3. Determine the concrete strength (concrete mix design).

### Table 1: Different type of concrete, grades, and application [8] [9]

| CG(M) | CMR(CSA) | CSMin(N/mm2) | CSMax (N/mm2) | CT | AP(1mpa=145.038psi) |
|-------|----------|--------------|---------------|----|----------------------|
| M5    | 1:5:10   | 4            | 5             | C4| 725psi               |
| M7.5  | 1:4:8    | 6            | 8             | C6| 1087psi              |
| M10   | 1:3:6    | 8            | 10            | C8| 1450psi              |
| M15   | 1:2:4    | 12           | 15            | C12| 2175psi             |
| M20   | 1:1.5:3  | 16           | 20            | C16| 2900psi             |
| M25   | 1:1:2    | 20           | 25            | C20| 3625psi             |

Note. CG(M) = concrete grades, CMR(CSA) = concrete mix ratio, CSMin=compressive strength min, CSMax=compressive strength max, CT = concrete type, AP = application

4. Determine the material batching of the concrete component [10]
5. Determine the blending paste/texture and workability of concrete. It is usually 0.4, 0.5, etc. by weight or by volume [11]

Mass of cement =\( \frac{1}{13} \times \text{dry volume of concrete} \times \text{density of cement} \)
Mass of fine aggregate =\( \frac{4}{13} \times \text{dry volume} \times \text{density of sand} \)
Mass of aggregate =\( \frac{8}{13} \times \text{dry volume} \times \text{density of coarse aggregates} \)

6. Determine the transportation of the concrete to location by mechanical or manual means.

### 2.2 Step involved in ramping and flooring at automobile workshop [12]

1. Earth work, Landscape manually, setting of blocks and filling of hollow blocks with a weak concentration mix ratio of 1:5:8, and use a compactor for strong sub-base.
2. Coordinate pour slope, leveling the ground and framing the ramp with blocks, and secure sides with reinforcing bar.
3. Six-inches deep to enable all segments of the slope to be 150mm minimum deep in the construction.
4. Pour and screed the floor and incline with wet mix concrete of mix ratio 1:4:8.
5. Pour sidewalls and use direct, concrete pour to avoid concrete pressure on the sidewall
6. Expel the side and allow the concrete to cure.
7. Screed, brush scarcely clammy cement before it dries for the security of the floor and incline .This is called Concrete Flooring and Ramping

### 2.3 Concrete Ramp and Flooring Non-Destructive Testing (Schmidt Hammer)

According to David Corbett, 2019 [13] Rebound hammer is used to determine the strength of the concrete floor and ramp of the study.

1. Identify the positions of the sample to be tested (10 ≤ t ≤ 12) and use a rebound hammer grinder on the test surface, and position the solid test hammer at 90° to the test surface.
2. Send the Impact plunger by pushing the mallet towards the test surface until it springs out.
3. Push the solid test hammer against the surface at moderate speed until the effect is activated, taking necessary precautions and observation as recommended.
4. After the test the compressive strength of the sample defined.

### 2.4 Costing of Concrete Ramp and Flooring

1. Price determination for costing factors of current price of building material [14]
2. Price varies from location to location.
3. Volume rating of concrete
Total costing of concrete = Volume of concrete x price/1m³ [15]

3 RESULTS AND DISCUSSION
3.1 Analysis and Discussion of Concrete Making
Analysis of Concrete
The material selected and used are cement, fine aggregate and coarse aggregate.

To determine the mass of the concrete this involves the determination of the material mix design. The mix design ratio: **M7.5 is 1:4:8**: 25kg/head-pan of cement, 4x25/ head-pan of sand, and 8 x25kg/head-pan of granite

Volume of concrete = length x width x height =1m³ (wet volume of concrete)
From building standard [11]: dry volume of concrete =1 + 54/100 x 1 = 1.54m³
Considering grade of concrete M7.5 having ratio (1:4:8), Ratio Sum = 1+4+8 = 13

For coarse aggregate (granite): 1m³ = 8/13 x 1.54 = 0.95 m³
1kg = 8/13 x 1.54 x 1500(weight of granite) =1422 kg

For fine aggregate (sand): 1m³ = 4/13 x 1.54 = 0.47 m³
1kg = 4/13 x 1.54 x 1450(weight of sand) = 687.08 kg

For Cement: 1m³ = 1/13 x 1.54 = 0.12 m³
1kg = 1/13 x 1.54 x 1440(density of cement) = 172 kg

From the Construction Concrete Mix is 1: 4: 8.
- Aggregates - 1422 kg
- Sand - 687.08 kg
- Cement - 172 kg
- Water - 150 kg (1 Litre of water = Mass of 1kg of Water)
- Air - 1.2929 kg (1m³ of Air = 1.2929kg)
Total = 2432.4 kg

From the Standard Construction Mix [16]: **1m³ of M7.5 Concrete Mix weights = 2500kg**
Result and discussion of mass concrete mix design M7.5
From the automobile cars and their standard curb weights, structural analysis and building construction standard the concrete mix ratio of M7.5 with a compressive strength of 8 N/mm² and a standard mass of 2500kg is suitable for the design [23-25].

Table 2: Automobile Cars and Standard Curb Weights [17] [18]

| Vehicle class          | W(lb.) | W(kg.) |
|-----------------------|--------|--------|
| Large car             | 4,366  | 1985   |
| Compact truck or SUV  | 3470   | 1577   |
| Midsize truck or SUV  | 4259   | 1936   |
| Large truck or SUV    | 5411   | 2460   |

Note. W (lb.) = weights in pounds, W (kg.) = weights in kg, 1kg = 2.2lb
3.2 Analysis and Discussion of Concrete Ramp

Analysis of Concrete Ramp

Figure 5: The ramp projection

From the physical construction measurement as shown above;
Slope of the ramp = gradient = \( \frac{700}{7800} = \frac{1}{11} \) (physical measurement slope = 1:11)
Slope of the ramp = gradient = \( \frac{700}{7000} = \frac{1}{10} \) (plan measurement slope = 1:10)

From building construction standard, the gradient of the concrete ramp is within safe limits recommended [19] [20].

Ramp length, \( L = \sqrt{700^2 + 7800^2} = 7831.35\text{mm} \)

Angle of inclination, \( \theta = \tan^{-1} \left( \frac{700}{7800} \right) = 5.13^\circ \)

Mechanical Advantage, \( M.A = \frac{1}{\sin \theta} = \frac{\text{Length of ramp}}{\text{Height of ramp}} \frac{7831.15}{700} = 11.13 \)

From the concrete ramp construction details,
Volume of the concrete ramp = area of triangle x weight = \( \frac{1}{2} \times 0.7 \times 7.8 \times 3.0 = 8.19 \text{m}^3 \) [21]

Wet volume of concrete on ramp = 8.19m³

Dry volume of concrete on ramp = 1.54 x 8.19m³ = 12.613m³

Mass of coarse aggregate = \( \frac{8}{13} \times 12.613 \times 1500(\text{density of aggregate}) = 11,642.8 \text{kg} \)

Mass of fine aggregate = \( \frac{4}{13} \times 12.613 \times 1450(\text{density of sand}) = 5,627.34 \text{kg} \)

Mass of cement = \( \frac{1}{13} \times 12.613 \times 1440(\text{density of cement}) = 1,397.13 \text{kg} \)

From building standard 1m³ = 2500kg, 12.613 m³ = 31,532kg

Result and discussion of concrete ramp
With a M.A of 11.13 = 31,532kg x 11.13 = 350,946kg = 351Tonnes

According to Silverman, Buffy (2009) Concrete ramp with a concrete Mix 1:4:8, M.A of 11.13 can leverage a load of 351tonnes [22]. From the manufacturer’s gross vehicle weight rating with a net weight of cars is 2600kg, while the gross vehicle weight rating is 5171kg. With a safety factor of 1.5, meaning curb weight (3900kg) and gross weight (7757kg). From above, the concrete ramp of 351tonnes is sustainable.

3.3 Analysis and Discussion of Concrete Flooring
1. Analysis concrete floor pit shelter is

![Figure 6: Extended pit shelter floor plan](image-url)
Concrete flooring area $CFA$: 5000mm x 8000mm (automobile pit shelter)
Thickness of concrete flooring $CF_T = 150mm$ (140mm ≤ $t$ ≥ 160mm)

Let: volume of concrete flooring pit shelter area with concrete = $VCFAw_c$
$VCFAw_c = 5000mm \times 8000mm \times 150mm = 6,000,000,000mm^3 = 6 \times 10^9$ mm$^3$

Let volume of concrete flooring pit shelter area without concrete = $VCFAw_w$
$VCFAw_w = 770mm \times 5600mm \times 150mm = 646,800,000mm^3 = 646.8 \times 10^6$ mm$^3$

Volume of concrete flooring pit shelter area = $6,000,000,000 - 646,800,000$
= $5,353,200,000mm^3 = 5.353 \times 10^9$ mm$^3$
= 5.3m$^3$

2. Analysis concrete floor outdoor & drive way area

Volume of concrete floor outdoor, drive area = $(20.8 \times 7.2 \times 0.15) + (13.8 \times 3 \times 0.15)$
= 28.674m$^3$

3. Analysis concrete floor inspection pit area
Figure 9: Concrete floor inspection pit area

Volume of concrete floor inspection pit area = $2[5.6m \times 1.8m \times 0.15m] = 3.02m^3$
Total volume concrete flooring = $5.3 + 28.674 + 3.02 = 36.994m^3$
Wet volume of concrete on flooring = 36.994m$^3$
Dry volume of concrete on flooring = $1.54 \times 36.994m^3 = 56.97m^3$
From building standard $1m^3 = 2500kg$, $56.97m^3 = 142,425kg$
From building construction standard, M7.5 mix ratio $1:4:8 = 13$
Mass of coarse aggregate used = $8/13 \times 56.97 \times 1500$ (density of aggregate) = 52,588.393kg
Mass of fine aggregate used = $4/13 \times 56.97 \times 1450$ (density of sand) = 25,417kg
Mass of cement used = $1/13 \times 54.65 \times 1440$ (density of cement) = 6310.523kg
From the manufacturer’s gross vehicle weight rating with net weight of cars is 2600kg, while the gross vehicle weight rating is 5171kg. With a safety factor of 1.5, meaning curb weight (3900kg) and gross weight (7757kg). The above concrete floor of $142,425$ tonnes is sustainable

3.4 Analysis and Discussion of Concrete Flooring and Ramp Testing

1. Analysis and discussion of non-destructive testing on concrete ramp

Table 3: Non-destructive testing on concrete ramp

| Variable | NI | YS (N/mm$^2$) | DHL |
|----------|----|---------------|-----|
| CR 1     | 7.78 | --            | --  |
| CR 2     | 6.90 | 6.90          | --  |
| CR 3     | 6.58 | 6.58          | 6.58|
| CR 4     | 6.79 | 6.79          | 6.79|
| CR 5     | 5.98 | 5.98          | 5.98|
| CR 6     | 6.85 | 6.85          | 6.85|
| CR 7     | 5.98 | 5.98          | 5.98|
| CR 8     | 7.60 | 7.60          | 7.60|
| CR 9     | 6.93 | 6.93          | 6.93|
| CR 10    | 5.96 | 5.96          | 5.96|
| CR 11    | 7.70 | 7.70          | 7.70|
| CR 12    | 5.95 | --            | --  |

Note. CR = concrete ramp, NI = no of impact, DHL = deduction of highest and lowest value
YS = Yield Strength
Average rebound value AVR = sum of total value / no of impact
= $\frac{67.29}{10} = 6.73$N/mm$^2$
2. Analysis and discussion of non-destructive testing on concrete flooring

Table 4: Non-destructive testing on concrete flooring

| Variable | NI | YS (N/mm²) | DHL |
|----------|----|------------|-----|
| CF       | 1  | 6.95       | 6.95|
| CF       | 2  | 6.85       | 6.85|
| CF       | 3  | 5.98       | ----|
| CF       | 4  | 6.99       | 6.99|
| CF       | 5  | 7.68       | 7.68|
| CF       | 6  | 7.79       | 7.79|
| CF       | 7  | 6.98       | 6.98|
| CF       | 8  | 7.85       | 7.85|
| CF       | 9  | 7.70       | 7.70|
| CF       | 10 | 7.95       | ----|
| CF       | 11 | 7.60       | 7.60|
| CF       | 12 | 3.99       | 3.99|

Note. CF = concrete flooring, NI = no of impact, DHL = deduction of highest and lowest value
YS = Yield Strength

Average rebound value $AVR = \frac{\text{sum of total value}}{\text{no of impact}}$

\[
= \frac{71.4}{10} = 7.14 \text{N/mm}^2
\]
3. Analysis and discussion of non-destructive testing on concrete around inspection pit

Table 5: Non-destructive testing on concrete inspection pit

| Variable | NI | YS (N/mm²) | DHL |
|----------|----|------------|-----|
| CIP      | 1  | 7.78       | 7.78|
| CIP      | 2  | 7.98       | ----|
| CIP      | 3  | 6.99       | 6.99|
| CIP      | 4  | 6.89       | 6.89|
| CIP      | 5  | 7.08       | 7.08|
| CIP      | 6  | 5.78       | ----|
| CIP      | 7  | 6.98       | 6.98|
| CIP      | 8  | 7.60       | 7.60|
| CIP      | 9  | 6.95       | 6.95|
| CIP      | 10 | 6.98       | 6.98|

Note. CIP = concrete around inspection pit, NI = no of impact, DHL = deduction of highest and lowest value, YS = Yield Strength

Average rebound value AVR = sum of total value / no of impact

\[ \text{AVR} = \frac{56.25}{8} = 7.03 \text{N/mm}^2 \]
Figure 12: Concrete inspection pit test graph

The concrete ramp, flooring, and inspection pit compressive strength (6.73N/mm$^2$, 7.14N/mm$^2$, 7.03N/mm$^2$) justifies the classes of concrete according to EN206-1 with a minimum compressive strength of 6N/mm$^2$ and maximum of 8N/mm$^2$ [8]. A little below the maximum could be as a result of the mixing method, curing and type of material mix conditions.

3.5 Analysis and Discussion for Costing of Concrete Flooring and Ramp

1. Price determination
Assume current prices of building material are:
- 7tonnes of very smooth/plaster sand = ₦28,000 (₦ 4/kg)
- 20tonnes of 1inch coarse aggregate (granite) = ₦90,000 (₦ 4.5kg)
- 50kg of cement = ₦2800 (₦56/kg)
- 10tonnes of clayey red laterite = ₦15000 (₦ 1.5/kg) and others.

2. Price of concrete vary from location to location.
The price of 1m$^3$ of concrete = 1USD/ m$^3$
From building construction standard in Nigeria, the price vary from location to location, the current rate of re-forced in-situ (1:4:8) concrete = ₦30000 – ₦35000/m$^3$
Current rate of plain insitu concrete (1:4:8) = ₦30000/ m$^3$

3. Volume Rating of concrete

Table 6: Costing analysis of concrete flooring and ramp

| COMPONENT | CM(Kg or M$^3$) | CR(Kg/M$^3$) | CF(Kg/M$^3$) | CR+CF(Kg/M$^3$) | PRICE (₦/Kg) | TOTAL(₦) |
|-----------|-----------------|--------------|--------------|-----------------|--------------|-----------|
| MCA       | 1421kg          | 11642.5kg    | 52,588.59kg  | 64230.69kg      | 4.5kg        | 259,038.11|
| MFA       | 687.08kg        | 5627.34kg    | 25,417kg     | 31,044.34kg     | 4.0kg        | 124,177.36|
| MC        | 172kg           | 1397.03kg    | 6310.52kg    | 7,707.55kg      | 56kg         | 431,622.8 |
| MW        |                 |              |              |                 |              |           |
| MA        |                 |              |              |                 |              |           |
| Concrete Volume 1M$^3$ | 12.613M$^3$ | 56.97M$^3$   | 69.583M$^3$  | 300000M$^3$    | 2,087,490   |
| Standard Mass 2500kg | 31532kg       | 136,625kg    | 168,157kg    |                 |              |           |
Note. CM=concrete making, CR=concrete ramp, CF=concrete flooring, MCA=mass of coarse aggregate, MFA = fine aggregate mass, MC= cement mass, MW=water mass MA= air mass

Direct Cost: Material (₦844,838.27), no labour cost, no equipment cost

Indirect Cost: no overhead, administration, personal security cost etc.

Due to the fact some cost parameter cannot be determined; a buildup cost from building that vary from location to location is used.

Total costing of concrete flooring and ramp = Volume of concrete x price/1m³ = ₦2,087,490

The cost of concrete flooring and ramp of the automobile lube bay shed is optimized for use [15].

Conclusions

Concrete floor and ramp structure aim to provide an environment friendly and sustainable automobile lube bay shed had been structurally analyzed and tested to validate the sustainability of concrete flooring and ramp.

Recommendations

In this study, the following recommendation is made to improve the current state-of-art of concrete flooring and ramp structures for sustainability and reliability.

- All causes of slips, trips and falls, contaminants, loss of surface grip, obstacles and other trip hazards should be avoided using slip-resistant footwear, electrical hazard rated footwear and other ergonomically safe personal protective equipment.
- Energy conservation through leveraging a weight uphill should be encouraged.
- Weight should not be kept permanently on the ramp floor due to uneven compressive strength and sustainability.
- Concrete grade should be selected based on functional strength specification and material availability, not only on mix ratio.
- Structural policies and plans should be made simple and understandable by personnel in the construction unit.
- A professional should be involved in the design and construction of structures.

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