A Design Methodology to Evaluate the Sustainable Construction for Temporary Structures

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Abstract: The rate of construction work growing day by day which gives an output of huge manpower and resources. As the construction work increases proportionally, the natural resources are being depleted and the conventional structures also have some effects on the environment. The usage of concrete for temporary structures should be gradually reduced and in future the concept of sustainability should be implemented in the construction works. The objective is to do a comparative study between the conventional structure and the structure made with sustainable materials. A model of the temporary structure (Bus stand) is created with different design considerations. It is based on the building oriented Energy model (using solar panels) and this model is calibrated and validated by comparing results obtained in Staad.ProV8i with in situ measurements realized. The design results from Staad.ProV8i reflect the load intensity and behavior of structure such as deflection, bending moment to external loads were analyzed. The material characteristics were studied for different materials like waste embedded epoxy tile, PE mesh panel and Ultralite that are used in the temporary structure. The methodology adopted in making the bus stand model is grooving technique, bolting and shear jointing. The members of the temporary structure are made of scrap steel which have the dimensions of 0.23m x 0.23m and analyzed for different support conditions includes, fixed support with more joints, pinned support with low joint, pinned support with more joints and fixed support with low joint to obtain their properties. Strength test and specific weight test were performed for different materials in which sustainable material shows considerable results. The structure has many advantages like light weight, portability, less labor consuming and time saving.

1. Introduction
Shelter is one of the basic needs of all human being. Temporary shelter should be the one which meets certain needs like ensuring safety, provides protection from natural elements and calamities. The need for temporary shelters has been increased greatly over the years for various purposes such as exhibition stalls, camping units and isolation wards, etc. They were required at different places at different period of time for a short duration [1]. The need for temporary structure has been greatly increased accounting the huge number of increase in homeless people all around the world. Those people don’t need a luxurious residence, all they need is just a roof which can even built by cardboard [5]. The temporary structures doesn’t need to follow the standard guidelines. The guidelines are very unique for these types of structures [6]. “Tactical urbanism” is a low cost - temporary change approach
to the urban environment that can act as a pop-up solution for built environment. Moreover, there were many case studies that offered a domestic solution for local planning challenges with short-term action for long-term change where (low risk / high reward) urban change can be happened [2].

In 2018, India was the second largest producer of cement in the world. The country had about eight percent of the global installed capacity that year. Consumption of cement at this time stood at around 270 million metric tons. Cement is the major cause for the CO$_2$ emission in the environment. Hence it is essential to look after construction using less consumption of cement or avoiding its usage. Instead of steel reinforcement system, bamboo modular system can be used [3]. Epoxies are considered as one of the widely used binder material in civil and construction industry. The excellent properties of epoxies includes, higher mechanical strength, low shrinkage, high abrasion resistant, gives good bonding to the building materials, etc [4]. Such epoxy is used for making a sustainable tile suing hardener and waste bottle caps.

The main objective of the research work is to describe the optimal design strategy, sustainable materials that can be used and finest methodology for the construction of a temporary bus shelter. Even bus stops can be designed as a temporary structure when they are required for a temporary duration of time. The ideology can be executed for all kinds of temporary structures, but basic needs should not compromise. At present, many were unaware the basic difference between temporary structure and permanent structure. By ignoring the consideration of this difference, there will be lot of effects in design aspects which result in loss of construction materials and economy. It is highly important to consider the load carrying capacity and life span of the structure.

2. Existing Construction Materials and Methodology

The most commonly used material for construction irrespective of their type is concrete structure. Usage of steel framed structures with cement roofing sheets or some other types of sheets is nowadays popular. The construction methodologies of these structures are very laborious process which even requires lot of tools and machineries for installation. For a concrete construction made with simple structure, it requires earthwork, foundation making, marking for column positioning, bar bending, shuttering, brick work and plastering. While considering the conventional steel structure, it is almost labor intensive. It requires skilled personnel for handling of equipments for erection, bolting/welding.

3. Construction with sustainable material and methodology:

3.1 Materials

Temporary structures being less load bearing structures which are made of different type of composite materials or recycled materials. These structures can be preferred nowadays but which are not as strong as conventional one’s. Temporary structures can meet the required strength if we use certain materials like Waste embedded epoxy tile, Polyethylene (PE) mesh panel, ultralite panel and recycled panels.

3.1.1. Waste embedded epoxy tile

Epoxies being a great binder material. This resin can be used as a binder to prepare tile which can be further embedded with waste materials like fibers, glass pieces, husk etc. The tiles made with waste embedded epoxy are strong in nature as like the conventional one.

The epoxy tiles are renewable and are considered as one of the sustainable material. Instead of embedding with waste, epoxy can be also used in making of mortar and concrete by mixing it with mineral fillers [7].
3.1.2. Polyethylene (PE) mesh panel

PE foam is a kind of polymer which acts as an insulator. They cannot be recycled even when incinerated or dumped after use. These PE materials cause harm to environment as they are not degradable in nature. Instead of throwing in scrap yard, these PE materials can be sandwiched between two meshes thus forming a thermal insulating panel. It is highly resistant to water which is considered as one of the major advantage.

3.1.3 Ultralite panel

Ultralite panels are readily available commercial product. For making any temporary structures, instead of using conventional cement roofing sheet, these ultralite panels are much preferred. They are designed in such a way that it transmits light without transferring heat to the shelter. It also has some of the advantages includes, light weight, ductility, UV stable, easy fitting, anti-glare and fire safety.

3.2. Methodology

The prefabricating technique can be adapted in construction works, in which the members are assembled in such a way they can be easily transported and erected in site without the need of mechanized tools or laborious works [8].

3.2.1. Grooving

Grooving is a mechanical process of making a narrow indentation in the material. For temporary structure, using this grooving technique, a small groove was formed in the member panels for easier insertion. This technique is less laborious and less time consuming process which also helps in easy assembly and disassembly of the structures.

3.2.2. Bolting

Bolting is the simplest methodology that can be used in the construction of temporary structures. Members can be joined by bolting which does not require a heavy tools or great workmanship. It also adds advantages such as easy assembly and dismantling of members. Bolted connections are rigid and it gains strength from the moment when bolted. It does not require any cooling time.

3.2.3. Shear joints

Shear joint is considered as a potential plane of shear. They consist of fasteners that capture and join other parts and are secured with the mating of screw threads. This connection helps to serve the better interlocking pattern which saves lot of time and material requirements.

3.3. Design variations

The temporary structures must be designed in such a way that it should not compromise the strength aspect. Different kinds of design were chosen for the proposed structure and analyzed using Staad.ProV8i. Figure 1 shows the conventional design whose members were made of ordinary concrete. The dimensions of the members are taken as 0.23mx0.23m with fixed support condition.

Though this condition can take a significant load, but for temporary structure there is no need for this kind of design which will lead to huge material loss and it is also considered as a laborious process. Figure 2 shows the four cases of design in which steel is used as main members which can provide the same strength as that of concrete. The support can be fixed if they are meant to serve for long time. The structure can be easily transported from one place to another, if the support conditions are hinged. Increasing the number of joints, it makes the structure in ease of assembly and disassembly.
Figure 1. STAAD pro design of structure made by concrete members

Figure 2. (a) Fixed support with more joint  
(b) Pinned support with low joint
4. Results and discussion

4.1. Deflection of conventional concrete structure

Figure 2. (c) Pinned support with more joint  
(d) Fixed support with low joint

Figure 3. Displacement of conventional concrete structure
Figure 3 shows the post processing process which shows the displacement diagram for a conventional concrete model. Since these are temporary structures, load combination differs from the ordinary structures. The load combinations of dead and live load of the structure alone are given as external load for the structure. Wind load is not accountable since the structure is of medium height. The load intensity is taken as 1kN/m for the members. The external load combination is applied for all type of support conditions and their corresponding deflections were obtained.

From figure 3, the conventional concrete structure does not show any deflection (zero deflection), but the modeled temporary steel structures shows a slight negligible deflection is shown in figure 4. The maximum deflection 0.7 inches occurs in more pin jointed structures.

Figure 4. Displacement of temporary steel structure
4.2 Bending moment
For the same loading condition, the maximum bending moment are also analyzed for all the support conditions. The bending moment does not vary for concrete as well as steel structures. Figure 5 shows the bending moment diagram for conventional concrete structure and figure 6(b) and figure 6 (b) for modeled steel structure. From the bending moment values, the structure is considered as a stable one. The maximum bending moment that occurs in the top member of the concrete structure is 0.103kN/m is shown in figure 5.

![Bending moment of conventional concrete structure](image1)

**Figure 5.** Bending moment of conventional concrete structure

![Bending moment of temporary steel structure for fixed support with more joint and pinned support with low joint](image2)

**Figure 6 (a).** Bending moment of temporary steel structure for fixed support with more joint and pinned support with low joint
Figure 6 (b). Bending moment of temporary steel structure for pinned support with more joint and fixed support with low joint

4.3. Strength test

Using epoxy resin, hardener and bottle caps three trails were conducted on waste embedded epoxy tile. Trial 1 is ceramic tile, trial 2 is made with epoxy tile after 5mins and trail 3 is epoxy tile after 180hours is shown in figure 7. The tiles were tested in compression testing machine. The results showed that, at early stage of molding, epoxy is comparatively weak and has a less strength. But once epoxy binds well it attains the ultimate strength which occurs in duration of 3 hour. The compressive strength of epoxy tile made after 3 hours is greater than the conventional tile.

Figure 7. Comparision of strength of tiles on various trails
4.4 Strength to weight ratio
Table 1 shows the strength to weight ratio for various materials. From these results, epoxy composites have the specific weight more than 1.5 which can be effectively used in construction for attaining the weightless structure.

| Material         | Specific Weight (Strength to Weight ratio) |
|------------------|--------------------------------------------|
| Concrete         | <0.7                                       |
| Aluminium        | 0.8                                        |
| Steel            | 1                                          |
| Titanium alloy   | 1.2                                        |
| Epoxy composites| >1.5                                       |

5. Conclusion
The research work concentrates on the innovative materials which can be best suited as an alternative for conventional materials. The made of Epoxy shows the considerable results which can be replaced with conventional materials used for the construction of temporary structures such as bus shelters, camping units and stalls. Design results are satisfactory which recommends the use of sustainable materials for temporary structures which ease the fabrication and cost.

Instead of using conventional way of approach for temporary structures, sustainable approach can be preferred. By implying sustainable concept in construction one can reduce huge laborious works, utilization of resources, construction process and time. Sustainable construction also reduces the impacts of environmental effects caused by conventional structures. They are also advantageous in its weight which leads to sustainable light weight structures.

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