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Proposed Geometry of Standard Precast Double Tee Floor Slab Members for Indian Markets

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Abstract: The use of precast Double Tee (DT) members for floor slabs is gaining popularity in Indian markets. However, no efforts have been made to standardize the process of precast engineering and manufacturing as happened in advanced countries. As such not much is known about the process of engineering of these members. In a prior research that is very related, a comprehensive market survey was conducted to understand the design and construction practices of precast double tee members in India. In that study, the authors collected the practices and preferences of precast engineers, builders, and manufacturers with regards to standard design parameters of these DT members such as span, factory-topped or field-topped members, thickness of slab, and prestressing properties. When the results of the survey were analyzed, it was found that there is no standard DT member developed or designed for Indian markets yet. Precast engineers design the member geometry and reinforcement for these DT members using detailed engineering methods. No standard geometry or designs are available for precasters and designers to quickly pick a member as a baseline for design in a process like the practice in USA where Precast/Prestressed Concrete Institute (PCI) provides standard DT member geometry and design for engineers to use. This paper identified this major gap in Indian markets and hence developed a standard DT member design. A standard DT member geometry is proposed for typical application as floor slabs in residential and office buildings for Indian standard code specifications. This standardization is made keeping in mind the constraints set by precast manufacturing processes, crane capacities, truck hauling capacities and highway load limits in the context of Indian socio-economic-cultural and construction practices. The cross section of the proposed standard member along with material properties and specifications of the ingredient materials is presented. Finally, the need for developing a full set of standard member designs and guiding design tables for varying spans and loads is put forward.

Keywords: Precast, Double Tee, DT, Slab, Geometry, Engineering

1. Introduction and Background

To quickly introduce the readers to what inspired this research and provide a background on the work done so far, the authors walked the readers through the history of precast DT engineering and the market survey conducted to understand the precast DT trends in Indian markets. In the US, the Precast/Prestressed Concrete Institute (PCI) had been very instrumental in developing standard precast DT member designs. PCI developed their handbook [1] expanding on the research contributions of many authors in the development of precast member design and construction. The process of standardization of DT members in the US helped the precast industry flourish very rapidly. Figure 1 shows a standard 12ft wide (4m) precast DT from PCI tailored to the specifications of PCI and American Concrete Institute (ACI) [2] codes. The engineers and precast manufacturers were able to quickly design and construct these members adopting the standard DT member designs as baseline along with the supplementary design tables provided by PCI. This process made the entire process of design and construction of these DT members very smooth and streamlined. Precasters were able to automate the fabrication of these members in the plant environment with high levels of efficiency [3].

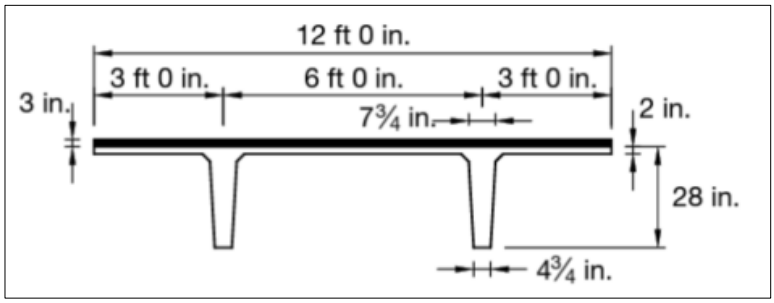

Figure 1: PCI 12ft Precast DT (Section taken from PCI MNL-120, 2017)

However, in India the situation is different, precast is just in the initial stages of popularity. No standardization of precast structural members has yet been attempted. Engineers and fabricators are relying on traditional design methods and practices to design and build precast DT member structures [4]. One reason is that no standard advisory body for precast industry in India such as PCI in United States which would bring precast engineers and contractors together to share their practices and knowledge. The other reason is that precast construction in India is still not as popular as traditional cast-in-place construction methods and is only evolving in recent years [5]. It will take some time for the industry to come up with common practices and standardization.

To understand the extent of precast utilization on the country and the level of standardization of precast member designs, a market research survey about Indian precast market was conducted [6]. The survey attempted to assess the awareness of precast double tee construction in India and to learn if there is a standard precast double tee geometry available in Indian precast industry. The survey inquired the participants about questions on capabilities and constraints with respect to fabrication, transportation, and erection of these members such that these things are kept in mind while proposing a standard member for the market in case no standard member is available. It was found that there is no standard precast double tee member available for Indian precast construction industry.

The current study attempted to develop a standard DT member geometry for floor slabs for residential, office and parking structures keeping in mind the observations and outcomes of the market survey. In the following sections, the major outcomes of the survey are discussed. Using the inputs and outcomes of the market survey, a standard member geometry is proposed for DT members keeping in mind the requirements and constraints of the market. Finally material properties and specifications are tabulated, and conclusions of the study are listed. The authors believe that having a standard DT member geometry serves as baseline for member design and greatly enhances consistency and harmony in the engineering of the members there by making the whole process of design and construction of DT structures easier, efficient and economical for all precast manufacturers, engineers and builders.

2. Major Outcomes of Survey

Before we get into the current study, let us quickly recap the important outcomes of the market survey [6] of the precast fabricators and engineers. The outcomes of the survey set the parameters of the current study to arrive at the standard geometry of the double tee suitable for Indian markets. Some major outcomes of the survey include the typical slab thickness, preference of field-topping verses factory topping, the typical spans, the constraints associated with precast plant operating capacities, the constraints associated with gross vehicular weight limits set by highway authorities among other things. Table 1 below presents the questions posted and responses received from the market survey published to precasters and engineers after permission from the authors of the market research study

Table 1: Survey Questions and Responses (Reproduced with permission from the authors of market research study [6])

#	Questions	Responses			
1	Are you aware of the PCI precast DT beam	Yes (85%)	No (15%)		
2	Has your company ever manufactured precast DT beam	Yes (55%)	No (45%)		
3	What kind of projects are most commonly built using precast DT beam	Residential (0%)	Commercial (30%)	Bridge decks (28%)	Parking Structures (42%)
4	What is the most common span range for DT usage	Common spans are 39ft and 60ft			
5	What kind of precast DT members does your company build	Fully precast (60%)		Partially precast with CIP concrete (40%)	
6	What is the most common prestressing strand size used	10mm (15%) (3/8")	12mm (43%) (1/2")	14.2mm (0) (9/16")	15.2mm (42%) (0.6")
7	What is the common cast in place concrete thickness over the DT	50mm (30%) (2")	75mm (30%) (3")	100mm (40%) 4"	N/A
8	What is weight limit of DT that does not require special transport permit	20 Metric Tons of Member weight (44 Kip) Gross Vehicular weight of 30 Metric Tons (66 Kip) with Tractor Trailer Unit weight of 10 Metric Tons (22 Kip)			
9	What is the single major stopping issue against the use of precast DT	Most common answer was lack of awareness and not being a regular practice			
10	Would you be interested in a more detailed interview on this subject	Yes (10%)		No (90%)	

3. Proposed Geometry of the Standard Double Tee

The survey provided some good insights into the demands and needs of precast floor slab systems in India. Based on the survey responses, it is evident that there are several constraints in the evolution of the geometry of the standard DT. There are several constraints in the process of coming up with a standard DT that can serve as baseline for designers and engineers to work upon for building standard floor system using precast DT. The survey responses pointed to each of these constraints. For the precast fabricators, it appeared that the member weights are more of a concern than the member geometry. However, member geometry is directly related to member weights. The weight of the member is limited by crane capabilities during stripping the member off the precast bed and moving the member around in the plant to a storage area until the job site is ready for erection of members. The transportation of the members from precast plant to job site played the most important role in setting the constraints on the member geometry and weight. The maximum gross vehicular weight of the hauling truck and trailer is restricted to about 30 Metric Tons on Indian highways [6]. This means the total weight of precast DT member and the weight of truck and trailer together is limited to this weight. If we exclude the empty truck and trailer weight, the maximum member weight that can be carried is limited to 20 Metric Tons. This weight is set as maximum weight based on transportation and handling limitations.

The study [6] pointed out that the needs of the precast DT are almost evenly split between fully precast DT versus partially precast DT with field topping. The slab thickness ranged from 50 mm to 100mm. It seems logical to think that the fully precast members have slabs of about 100mm thick overall whereas the partially precast members have slabs that are 50mm thick. The partially precast members receive an extra 50mm field concrete topping. The typical spans of those DT that are being produced ranged from 39 ft to 60ft as seen on the survey. This constraint not only comes from weight limits but also from transportation limits on member geometry. It is also noted that most of the DT members being used are either for Parking structures or for commercial floor slabs. It seems logical to think that the 60ft members are ideal for parking structures whereas the commercial floor slabs could be closer to 40 ft span. While parking structures typically have live loads of 2 kN/m^2, the office floor slabs have about 2.5 kN/m^2 of load considered on them. The authors kept all the above constraints in mind while considering the needs of the projects and standard load and design specifications of Indian Standards [7] in arriving at the geometry of the standard precast DT members for Indian markets. It is interesting to note in the results of the survey that some of the DT members are used for bridge decks, because use of DT members in bridge decks is not common. It is likely that these decks are being used similar to PCI NEXT beams which are one of the applications of precast beam-slab members used for small and medium span precast bridge decks.

In total, the authors proposed four different member geometries in this study. Two geometries are proposed for parking structure floors, one for fully precast option and another for partially precast option. Similarly, two more geometries are proposed for office building floor members, one for fully precast and one for partially precast. Figures 2 and 3 presents the geometry proposed by the authors as floor members for parking structures for Indian markets for standard fully precast DT and partially precast DT members respectively. These geometries are proposed based on spans of 18m which is the most common span range for DT members in parking structures.

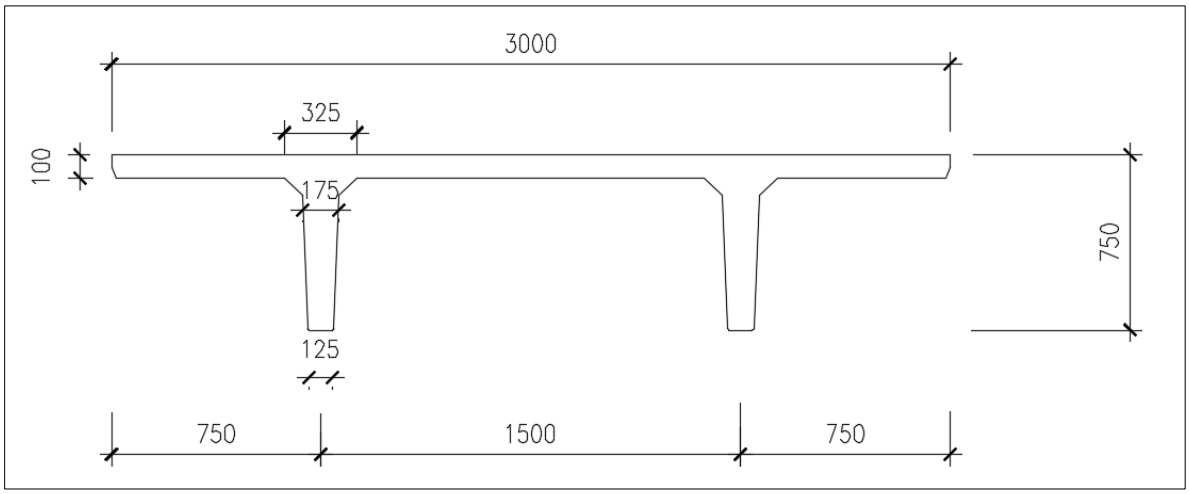

Figure 2: Proposed Sectional Geometry for Fully Precast Standard DT for Floor Members of Parking Structures for Indian Markets (*all dimensions in mm*)

The proposed DT section is 3m wide and 750mm deep for factory made members. The stems are 125mm thick at bottom and tapper to 175mm at the top. The stems have a 75mm chamfer on each side to further widen to 325 mm where the stem meets the flange slab. The stems are 1.5m center to center. The field topped DT member which is designed to receive a cast-in-place topping has same geometry throughout except that the flange slab is only 50mm thick and the overall depth of the DT member is 700mm.

It may be noted that this study presents the proposed geometry of the member. The design of the prestressing is not presented here because several design options are possible for different load levels, different spans, prestressing strand sizes and quantities. The authors intend to present the design possibilities in the form of design tables in a future study. The idea of this paper is to provide a standard geometry for the DT members that can be used as a template to develop DT members designs specific to the project.

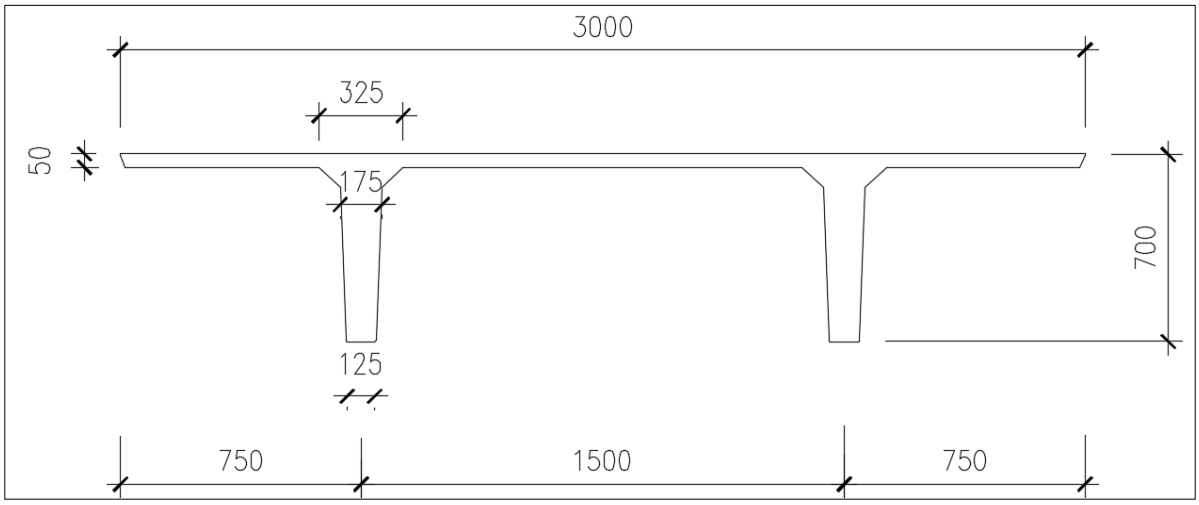

Figure 3: Proposed Sectional Geometry for Partially Precast Standard DT for Floor Members of Parking Structures for Indian Markets (all dimensions in mm)

While parking structures need DT members spanning 18m, the office floor members typically need much lesser spans. Based on the market survey, it is understood that DT members for office floors typically have a span of up to 12m. However, office floor loads are higher than parking structure loads. The office floors need to be designed for a live load of 2.5 kN/m^2. Keeping this in mind, separate sets of member geometries are proposed for DT members that are to be designed for office floor loads. Figures 4 and 5 present the proposed geometry for DT members to be used as floor slabs in office buildings in India.

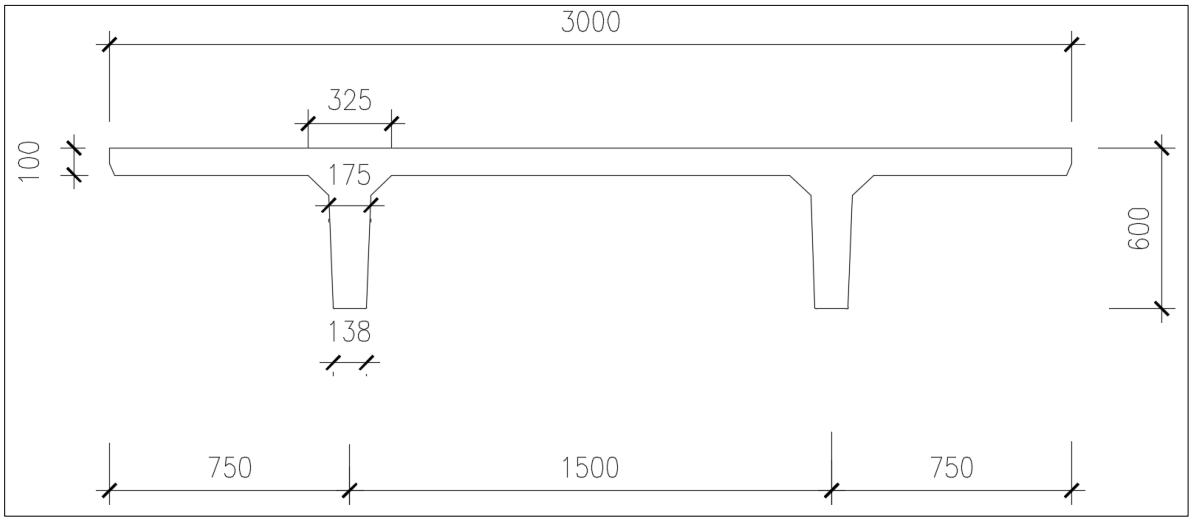

Figure 4: Proposed Sectional Geometry for Fully Precast Standard DT for Floor Slabs of Office Buildings for Indian Markets (*all dimensions in mm*)

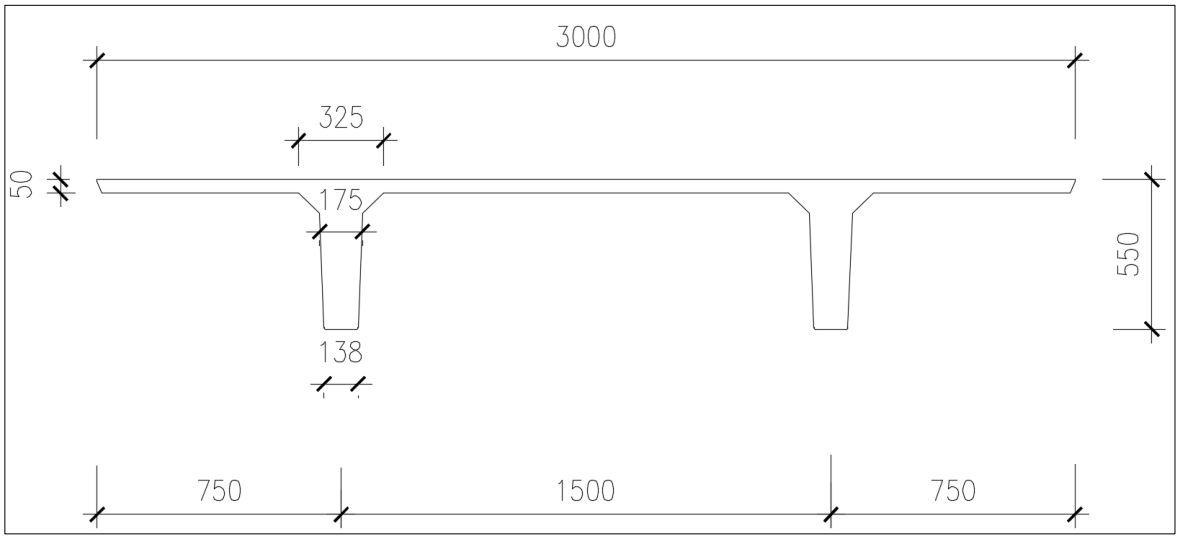

Figure 5: Proposed Cross Sectional Geometry for Partially Precast Standard DT for floor slabs of office buildings for Indian Markets (*all dimensions in mm*)

Figures 4 and 5 present the geometry proposed by the authors as office floor slab members for Indian markets for standard fully precast DT and partially precast DT members respectively. The authors proposed a shallower geometry for these floor DT members at depths of 600mm for fully precast and 550mm for partially precast because office floor spans rarely go beyond 12m. However, the stem width is kept in proportion to parking garage DT member so the same precast form can be used for these shallower members as well. It may be noted that these floor slab member geometries can potentially be considered for residential floor slabs because the residential slab span configurations and live loads are very close to office floor member spans and loads.

4. Material Properties and Specifications

In Table 1 below, the authors tabulated the material strength and specifications considered in the process of developing the standard precast DT member geometries presented in the previous section. As in any precast member design and fabrication process, strict quality control is paramount to achieving the specified strength and meeting the performance requirements of the members. Precast members are often fabricated using self-compacting concrete to avoid honey combing and achieve uniform mix consistency. Thermal or heat curing of the members while on the precast beds is performed to achieve quick early strength so that members can be stripped of the bed as soon as they reach the required strength to carry their self-weight [8].

Table 2: Typical Material Properties and Specifications for Proposed Standard DT

Property	Specification
Concrete Grade	M35
Strength at Stripping of members	20 MPa
Concrete Strength at Erection	35 MPa
Prestressing Strand Grade	1860 MPa
Prestressing Strand Size	12.7 mm
Supplemental Steel Yield Strength	500 MPa

5. Conclusions

This study referred to the previous work done on a market survey conducted with precast manufacturers and engineers to identify the typical, spans, loads, shipping and manufacturing constraints and weight limits on Indian highways. Based on the survey outcomes, the authors developed and proposed standard geometries for precast double tee (often known as DT) members. The proposed geometries considered the general and construction preferences as well as the handling weight, transportation weight and erection constraints. Overall, four different geometries (cross sections) are presented as potential standard precast DT members for the industry; One each for parking garage floor members and Office building floor members. A partially precast and a fully precast DT member each are proposed for each of the parking garage and office building floor members. This study does not include the design steel details of the member as there could are lot of variables such as span, load and prestressing quantities could be considered in the design of these members. A natural extension of this study will be to build design tables that capture all these variables. Another interesting study would be to develop similar sections using Ultra-High-Performance Concrete (UHPC) which is of large interest in civil engineering communities [9]. UHPC is novel high strength concrete usually with a mix of steel fibers to enhance the tensile strength of concrete significantly there by further reducing the weight of the members and amount of reinforcement [10]. UHPC enhances the strength, durability and performance of the structural members. Developing UHPC double tee members for precasters will provide significant improvements to efficiency and economy while also making them resilient to natural hazards [11] and add to construction sustainability by virtue of their robustness and longevity [12].

Disclaimer

The opinions and views expressed in this paper are completely based on those of the authors' and do not in any way represent the views or opinions of the affiliate organizations or institutes.

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