

On Highlighting the Need for Constructability Considerations When Evaluating Scope and Quantity Takeoffs for Estimates

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Courses in undergraduate estimating emphasize quantity takeoffs. Usually, discussions of constructability decisions and their impacts on scope and cost are not covered in these courses. The need for students to have awareness of constructability impacts on projects costs has been identified as a short-coming in construction management undergraduate education. Case studies and discussions have been cited as effective teaching tools. This paper discusses a case study derived from a construction project managed by the author that is used to illustrate the impact of constructability on a project's cost in estimating classes taught by the author. Execution decisions made by the contractor and scope and costs resulting from them were included in the final bid. The case lends itself to treatment of constructability impacts on scope and cost in multiple ways, and also lends itself to treatment of other estimating and cost related concepts useful in undergraduate construction management education.

Keyword: constructability impacts, undergraduate estimating, plan of attack, cost

Introduction

Direct costs encompass the majority of a project's budget. Costs for this budget component are determined by examining and quantifying the scope of the job as conveyed in the construction documents (drawings and specifications). However, an important cost component not necessarily quantified within the construction documents, but one that is integral to successfully establishing a budget that provides managers with a reasonable chance for successful project completion, is quantifying those activities that connote the project's execution plan.

The execution plan for a project, or its plan of attack and/or constructability elements, is developed by the construction company or companies, and is the plan or method that will be utilize to execute the scope of the work described by the construction documents. Execution plans for singular projects can vary and, and as such, costs for their execution can factor in determining the successful winning bid. Execution plans can result in additional scope and/or activity for the contractor in addition to that shown in the construction documents. All facets of direct costs, i.e., materials, labor, and equipment, can be impacted by execution plan decisions. Hence, incorporation of the costs associated with construction method decisions are necessary for establishing a realistic project budget.

Many estimating class and textbooks at the undergraduate level focus on quantity takeoffs. Some include pricing. Some discuss construction related activities like those associated with size factors, performance factors, and/or job condition factors; however, elements such as those are primarily functions of quantity takeoffs from the construction documents.

Activities associated with execution plans (also referred to here as constructability) and the costs associated with them, can vary from company to company, and can depend on factors too numerous to name and indigenous to individual companies' personnel and methods of operation. Yet, these factors should be considered, qualified, and quantified as their costs should be evaluated for budgets and bids.

This paper introduces two tools used to emphasize this component of cost in an estimating class conducted by the author. The purpose, here, is not to teach students who take estimating every methods of construction options available for particular scope and activities estimated in the course. Instead, the activities and the cases presented are used to increase awareness in students taking the course of the need to consider that elements associated with plans of execution should be evaluated for their impacts on the cost of the job. This should be done to ensure that bids submitted yield operating budgets with reasonable chances of success if the company is awarded the work.

Literature Review

Project execution planning skills and practical field experience have long been recognized as skill sets needed by construction managers (Mead & Gehrig, 1995). These skills allow managers to develop execution plans, i.e., constructability approaches or constructability, to execute the work contained in the construction documents. With the increasing use of computers, hand-held devices, and construction software for estimating, scheduling, and construction document generation (CAD, Rivet, etc.), activities associated with bid activity, estimate preparation, and document interpretation are becoming more automated (Smithwick, Mischung, & Sullivan, 2014). For example, software like ON-Screen Takeoff can lead to generation of accurate quantity takeoffs from the documents provided. Users need only to know the software to achieve this. However, the software does not include constructability activities or scope resulting from field execution strategies. Adjustments must be made by users based on his/her field experience and/or ability to develop and plan execution strategies. Users can then modify the software generated takeoff quantities to include any additional scope requirements that result from the execution strategy proposed for the work. Hence, an awareness of execution planning and activities that results from constructability decision, and means and methods of quantifying those activities, should be introduced to construction management students.

Construction management educators, while introducing construction management students to current best practices and tools of the trade, must ensure proper utilization of those tools – not blind reliance on and automatic acceptance of the outcomes and results from their use. Contractors have cited the need for more knowledge and inclusion of constructability considerations in estimating. A respondent from Kirk's survey of industry professionals noted good estimating requires the ability to apply construction expertise to the takeoffs (Kirk, 1997). The respondent also noted a troubling trend in the growing number of applicants for estimating jobs who were computer literate, but who had little knowledge about construction. He described them as computer whizzes who could not build. Construction estimating has been referred to as a blend of art and science (Woodward& Chen, 1999), (Mathis & Toole, 1986). The science aspects come from the applications of mathematics and formulas to derive a cost for the proposed work. The art aspects come from the fact that judgment and experience are key elements needed for successful cost determination. Opfer and Son's survey of contractors found that a number of industry professionals felt the single largest mistake in construction estimating education was too much focus [e.g. time spent] on basic trades' takeoffs to the detriment of other topical areas. Many noted the need for students to obtain field experience to supplement estimating skills. One respondent noted new graduates in their firm spend six months in the field as carpenters before assuming a field or office position. They also found many contractors were critical of some graduates for not truly understanding concepts of value engineering and constructability (Opfer and Son, 2002).

Sylvester and Dietrich observed that despite continual technological advances, estimating in construction education has remained relatively unchanged. Most courses still requires students to conduct time consuming quantifications and take-offs from construction documents. They note that the traditional estimating process results in a disconnect from the physical building process that leads to greater differences between estimated and actual construction costs. They also noted the significant technological advances in building information modeling that allow professionals to link components of three-dimensional computer models to costs databases. They state this helps eliminate error, reduces time, and alleviates some of the disconnect between the estimating process and the building process (Sylvester and Dietrich, 2010). While BIM and other software advances might help in some areas (clash detection, etc.), knowledge of construction processes, field execution, and the resulting scope and cost impacts is still required.

Finally, Monsey posits bad defective or bad estimates may be defined as estimates that differ from acceptable proposals by more than a reasonable amount, either in absolute monetary terms or percentages. The differences might result from the owner or the designer not including all the functional or other features that may have been desired on the project. Monsey used the standard method most use to arrive at cost, i.e. cost = quantity x price. He also stated it can be assumed that the exact value of either quantity or labor is the arithmetic mean of a small population and good data that describes or quantifies estimating variability is lacking (Monsey, 1988). “Good data” includes incorporation of requirements associated with the project’s plan of attack, or issues associated with construction of the project. Failure by the owner, designer, or contractor’s estimator to include constructability considerations could result in a poor bid.

The literature search points to the need to consider constructability in estimates and bids. This paper presents methods used to introduce awareness for the need to consider constructability in an undergraduate estimating class.

The San Bernardino, California Courthouse Mat Foundation

The first tool used to present the topic is a short video on the construction of a 6,000 yd^3 concrete mat foundation for the San Bernardino, California courthouse. Bomel Construction is the principal contractor for the work. This project was done at night and completed in 10 hours. The video’s introduction highlights some of the unique aspects of the job; some are constructability elements that would not be normally included in takeoffs of concrete work. Highlights cited were (1) four months of preparation and planning, (2) the partnership of over a dozen firms, (3) eight concrete boom pumps, (3) three batch plants, (4) 50 inspectors, supervisors, and flagmen, (5) 80 concrete trucks (one every four minutes), (6) 216 tons of crushed ice, and (7) 4000 trades workers labor hours (Bomel, 2012).

Students are asked to name and discuss items associated with this execution plan that might not be included when a standard takeoff just using construction documents was performed. Having seen the video’s listing of the items mentioned above, some of the items mentioned are from that list. When the question is refined to limit the discussion to those items associated with direct costs only, the ice is usually noted specifically as an additional item required by the execution strategy due to the heat generated by the massive amount of concrete. Additionally, however, student discussions note that the project was executed at night and that night differential for trade workers and the potential need for additional crew foremen are also items that have direct cost impacts.

The First Baptist Church East Basement Wall Project

The First Baptist Church East Basement Wall project replaced a failed basement wall at the church. The failure resulted from lateral pressure exerted on the wall by clayey soil when it was subjected to moisture. Although the wall did not collapse, its inward deflection and movement resulting from were beyond acceptable ranges. Additionally, excessive cracking existed in the wall. The problem was uncovered during the beginning stages of a project to remodel the church’s kitchen that is located in the basement of the church. The wall is approximately 40 ft. long by 10 ft. high. It is a CMU wall, with excess grout from its construction dump intermittently and randomly in some of the blocks’ cells. This writer served as project manager for the project.

After discussing potential solutions with the engineer hired for the job, this writer proposed a “containment” approach as a solution. This meant that the existing basement wall would remain (solutions discussed included removing the wall) and the wall would be enclosed by steel studs on its interior side and a new cast in place concrete wall, waterproofed, on its exterior side. The existing wall would be grouted and dowels would be inserted to tie the old wall and the new wall together for composite action. Also, non-shrink grout would be placed between the steel studs and the existing wall where gaps existed due to the existing wall’s curvature to prevent any further movement of the existing wall. Finally, drainage tile would be placed at the wall’s footer to collect and channel water away from the soil, and gravel backfill would be installed by the wall to facilitate drainage to the tile system.

Construction Documents

The drawings for the project prepared by the design professional are shown in figures 1 and 2. An aerial view of the project’s location is shown in figure 3. The rear property line is approximately eight feet behind the basement wall under repair. More than 9 ft. of the wall is below grade. The general contractor submitted a bid for $113,100 and provided a breakdown of the cost by work categories.

Case Discussion

The case discussion centers on scope items required due to the constructability approach used to execute the project. In addition to the drawings and the notes contained on them, the following information is noted by means of the aerial view photo (figure 3).

The church has a westward facing front elevation; the basement wall under repair supports the east elevation wall. As noted above, the church's rear property line is located about nine feet from the wall. A large clearing is located on the property adjacent to the church's rear property line and its owners allow church parishioners to park there, weather permitting, in exchange for the church keeping the grass cut. A retaining wall, owned by the church, is located about six feet behind the building's east wall. The clearing's elevation starts at the wall height, slopes upward for another one to two foot to about half way across the clearing, then slopes downward away from the church to a natural drainage bed located in the wooded area beyond the clearing. The wooded area is also owned by the entity that owns the clearing.

Local code requirements dictated one to one slope for excavations where mechanical protection is not utilize. The church has parking and driveways on either side of its structure with the north driveway providing access to the clearing behind the church. The driveways provided access to the construction area.

Constructability and Execution Decisions Made By the Contractor

The drawings shown in figures 1 and 2 were the only construction documents provided by the design professional. Listed first in the notes is a statement specifying that the contractor is responsible for means and methods of construction and that the drawings show the final installed work only and do not address the sequence or techniques to perform the work (figure 2). This statement also placed responsibility on the contractor for any additional scope resulting from constructability decisions costs arising from them. They were included in the contractor's final bid.

Execution (or constructability) related decisions made by the contractor, and discussion items for the case include

1. *Natural protection was used for the excavation instead of mechanical protection.* This required the church to obtain permission from the adjacent property owner. Permission was granted with the stipulation that the site be landscaped back to its original conditions. Hence, grading and seeding of the area was required after completion of the new wall construction.

2. *The one to one slope requirement for excavation and storing of removed soil in the clearing area eliminated any possibility of placing the concrete for the new wall via chutes from the truck.* Bank protection was used for the excavation, and angle of repose protection was used to store the removed soil.

3. *As a result of using natural protection, a concrete pumping truck was required.* As stated, driveways existed on both sides of the wall, and access was available along the entire wall. This could have facilitated the use of chutes for casting the new foundation wall.

4. *The use of natural protection also required removal of the existing stone and mortar three foot high retaining wall.* A new segmented block wall was used to replace it.

5. *Formwork required ties anchored to the existing wall instead of bracing.* This also resulted from the decision to use natural protection of the excavation. There was no place to externally anchor bracing. This meant additional drilling of wall to connect ties and grouting of ties for sealing, but it provided an additional element of composite action between the old wall and new wall.

6. *Additional piping was required.* Storm drain piping from the rear of the church to the county storm sewer did not exist. The rear roof downspouts located in the back of the church drained into the soil (and might have contributed to the wall's failure). The contractor proposed that water from the new wall's drainage system be discharged in the natural drainage course located in the wooded area on the adjacent property owner's property, and asked the church to secure permission and right of way. This required an additional 10 foot section of pipe. Permission was denied by the adjacent property owner citing a desire not to encumber the land in event of future sale. A new 160 foot section of pipe, beginning at the north side of the repaired wall and routed along the back (east) and north edges of the church's property, was necessary to utilize the county's storm water system.

7. *An internal temporary lateral support system to handle the lateral pressure exerted by the wet concrete.* This bracing was anchored to the steel studs and added along the entire interior side of the existing wall. It was removed after the concrete gained sufficient strength. This resulted from the formwork decision, also.

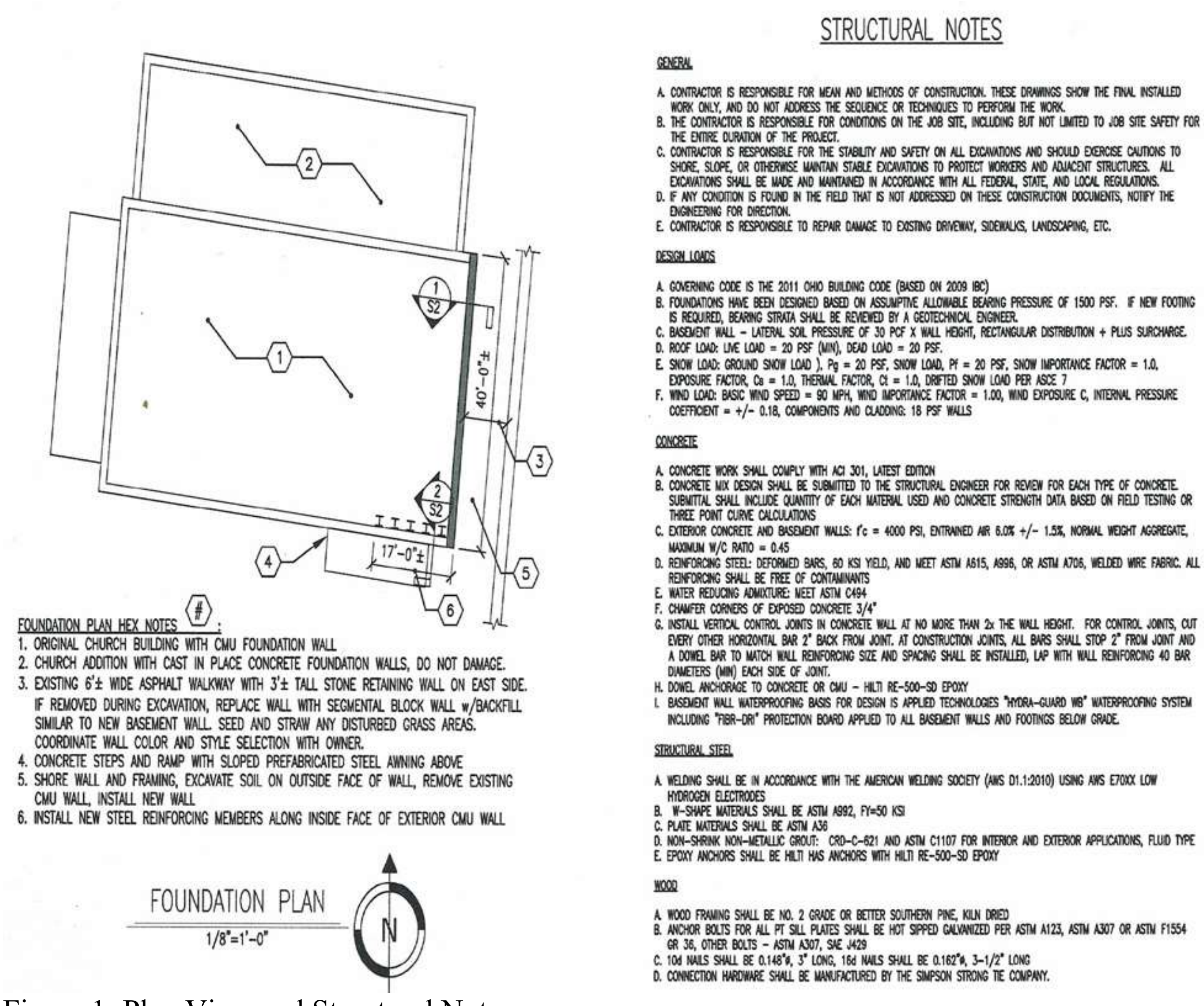

Figure 1: Plan View and Structural Notes

Advantages of Using This Case to Introduce Constructability Impacts To Students In Undergraduate Estimating Classes

1. Students generally have sufficient background in the project's technology. Estimating is a third year course in the writer's program; hence, students have been exposed to execution options for projects of this type. The author uses elements of this project in a freshman level materials and method course to illustrate natural excavation projection (both angle of repose and banking), drainage systems used to maintain site conditions, concrete placement by pumping, formwork systems, concrete vibrator usage, and alternative steel stud systems. Also, many of them have experience with the technology and systems utilized in this project through CO-OP.

2. The scope associated with the constructability decisions offered in the case is readily quantifiable and easily understood. Hence, the cost impacts associated with them can be determined. The contractor's estimate for the work is broken down into major work categories and can be used to compare estimates prepared by students.

3. The project can be estimated without final execution constructability requirements by using standard execution assumptions as a baseline (i.e., braced formwork, mechanical excavation protection, short drain-tile discharge, concrete placed by chuting, etc.). The constructability items can be added in the form of circumstances and issues that arise which affect the job. Cost comparisons can be made to the bids for the options submitted by the general contractor.

4. Activities for the project required no special adjustments for factors that could impact productivity; hence, standard takeoffs can be utilized. The external concrete wall and the activities associated (excavation, drain tile, etc.) with it was new construction. The area where the inside work took place was site-cleared by members of the church prior to construction start. Hence, the construction workers had clear and easy access to perform work required in the area. A multi-use area inside of the church near the construction was used for storage and pre-work.

5. Currently, the point of the project's study is to impress on students to consider the impacts of constructability/execution decisions on scope and costs when preparing estimates. Hence, the material can be introduced and covered in a couple of classroom sessions.

6. The project entails standard building elements and no special or unique requirements; hence, it lends itself to published estimating data bases and systems such as Means.

7. The scope for the project is made of systems that are normally covered, and takeoffs are performed for, in most estimating courses. Drain tile estimation can be added if this system is not covered.

Conclusion

Traditional estimating classes focus on takeoffs from drawings; therefore, critical scope can be missed. The need for constructability considerations in undergraduate estimating courses has long been recognized; however, a review of literature suggests additional course content on the topic is needed is needed in estimating courses. The author reviewed four current estimating textbooks; none expressly discussed constructability impacts on estimates.

This paper presents the impact of constructability decisions made by a contractor on final project scope and cost. The decisions resulted from meetings with the author and the design professional and were incorporated into the contractor's final bid. This provided the contractor the opportunity to develop a budget inclusive of all items necessary to execute the project based on the actual execution strategy for the work. The contractor's knowledge of constructability was crucial to developing the strategy and the scope and cost associated with it. The First Baptist Church East Basement Wall and the Bomel mat foundation project are used in the author's estimating course to press upon undergraduate students the need to consider constructability impacts on the scope and cost of estimates.

Advantages of using this case have been discussed. As noted, the information presented here is based on the final option selected for implementation. A conceptual estimate based on the engineer's primarily report, and an estimate used to bid the job based on a constructability plan that called for removal of the existing basement wall were also developed; hence, three estimates were developed. Customer decisions and/or unforeseen circumstances resulted in the selection of the option ultimately executed. This paper does not include discussion of early design options, nor decisions of events associated with moving to option ultimately executed. However, this information is available. Hence, this case can be used to show the impact of design options, and the impacts of customer decisions and unforeseen circumstances on constructability decisions and their costs. and used to increase the awareness of undergraduate estimating students.

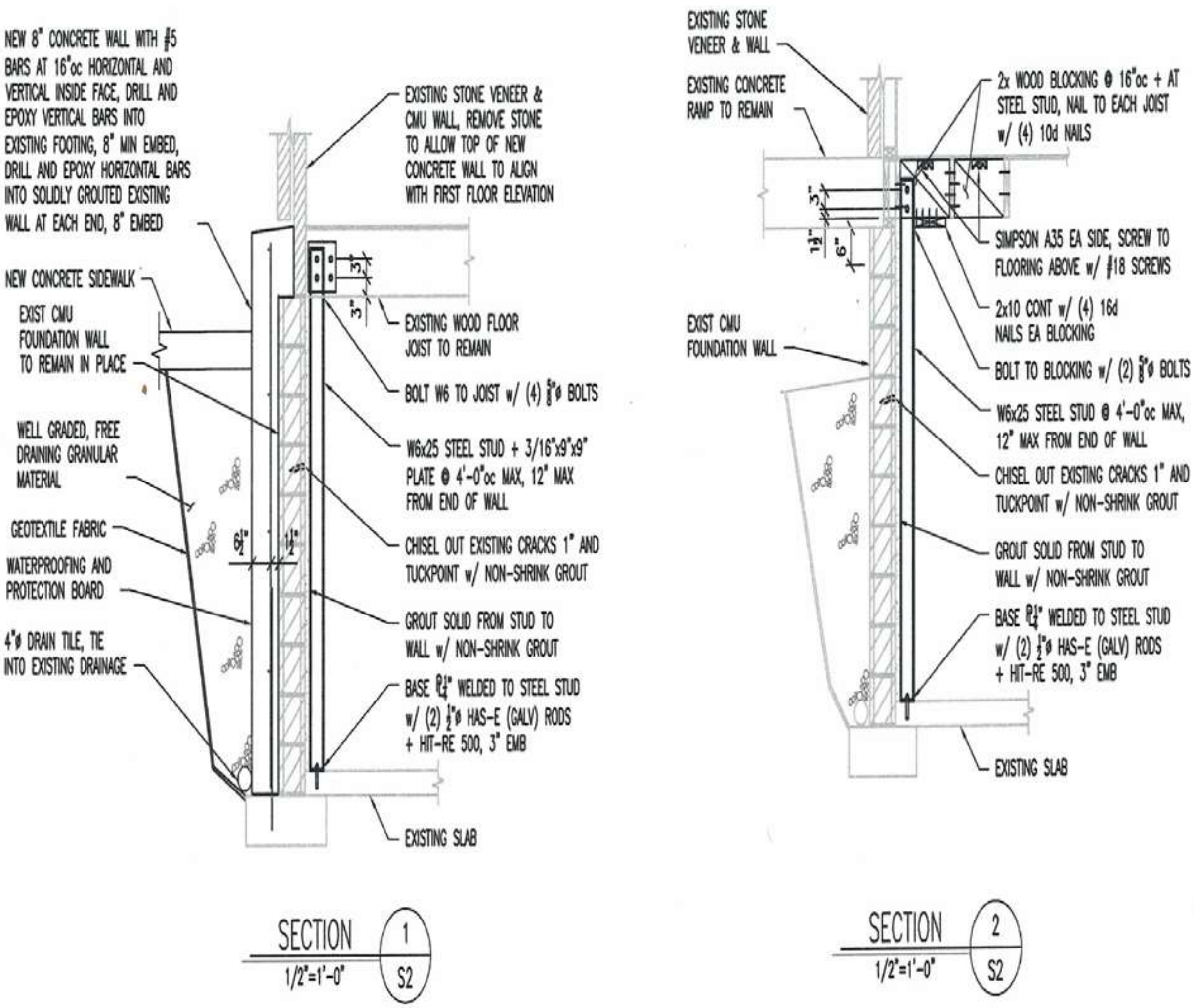

Figure 2: Exterior and Interior Wall Detail

The Bomel video and the case content discussed here are used as a lecture session tool to introduce and illustrate the need to consider constructability impacts on estimate costs. Currently, it is covered in one session. Hence, quantitative measurements of the discussions are not offered in this paper. Collection and assessment of that data will occur in future iterations of course that include use of the project in applications like those described in the above paragraph. As noted, industry has cited the need for more instruction in this area as little treatment of constructability impact on cost estimates is provided in current estimating textbooks, content, and courses. The information and content of this paper is offered as one tool for alleviating this shortcoming.

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Figure 3: Arial view of Property

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