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Research Article

An Experimental Study on Strength of Concrete Due To Cold Joints

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I N F O

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A B S T R A C T

In major infrastructure projects with huge concreting works, concreting works cannot be completed in a single day. Concreting works for infrastructures like major bridges, dams are done in intervals of days and weeks when concreting are done in large volume. It is not possible to complete mass concreting in a single day due to limitation of labor, unavailability of sufficient equipment, labor productivity and site conditions which leads to the formation cold joints. This study focuses primarily on by what means the strength of concrete is affected from cold joints formation and how the effect of such joints can be improved in the construction site. This study shows the variation of strength of concrete with various types of joints formed during placing of concrete. Compressive strength and Split tensile strength of concrete were observed during the test. It was found that the presence of joint reduced both the compressive strength and split tensile strength of concrete. The compressive strength of concrete was found to decrease by 22-25% in the case of cubes with joints while the split tensile strength decreased by 23%. The study also focused on the use of cement slurry (1:1) and chemical admixture on the cold joints and found that use of cement slurry reduced the loss in compressive strength by 30.80% in case of concrete with vertical joints and 13.82% in case of split tensile strength of cylinder. Chemical admixture also showed improvement in compressive strength by 21.50% and split tensile strength by 17.51%. However, improvement in compressive strength of concrete with horizontal joints with the use of chemical admixture or cement slurry didn't show satisfactory results. This study recommends surface treatment of cold joints with cement slurry or chemical admixture when concreting in large volume to avoid the effects of cold joints.

Keywords: Cold Joints, Mass Concreting, Compressive Strength, Cement Slurry, Chemical Admixture

Background

Cold joints in concrete are the plane of weakness which is usually caused due to an delay in the concreting operations when the first batch of concrete start setting or has

already set before the next batch arises so that the two batches do not intermix with each other. Formation of cold joints during construction is a sign of mal construction practice but usually in the case of mass concreting where concreting works requires days to complete, cold joints are unavoidable. This interruption in casting process can affect the structural perfomance (Harsem, 2005).

Cold joints can be observed in major infrastructures like bridges, dams, overhead water tanks, buildings which involves large amount of concreting. The delay in concreting is caused due to limitation of labor, unavailability of sufficient equipment, improper site organization, ineffective work scheduling, labor productivity, breakdown of equipments during mass construction which leads to formation of cold joint. Cold joints are planes of failure caused by disturbance in casting practice that affects the structural behavior. In such cases care should be taken while concreting the fresh mix with set concrete since the cold joints formation already occurs. It can be seen mostly in different construction sites that the concreting is done without cold joint treatment. Since cold joints in concrete are one type of crack in concrete these can lead to further crack development in the future and also structural failure. This study focuses primarily on how the strength of concrete is affected due to cold joints and how cold treatment can recover the loss strength of concrete.

When the concreting process is not completed monolithically, failure planes can be seen in the form of cold joints. The reduction in compressive, flexure and split tensile strength was least in the case of horizontal plane as compared to vertical and diagonal planes when cold joints are formed (Rathi & Kolase, 2013). The magnitude of effect is also determined by the position of the joint within the structure, the structural function of the element and aesthetics that need to be reflected when considering a cold joint. The compressive strength declined by 1.06%, split tensile strength by 3.93% while flexural strength by 4.02% when delayed in concreting was done after 60 minutes with respect to sample without joints (Bekem Kara, 2021) fresh concrete was poured into molds filling them half in order to create a horizontal cold joint and after 0, 60, 120 and 180 min additional concrete was poured to top off the molds. The specimens were subjected to compressive, flexural, splitting tensile and concrete steel rebar pullout testing. In the second part of the study, two types of concrete were prepared to carry out durability experiments. Concrete specimens with and without cold joints were subjected to drying–wetting, freezing–thawing and high temperatures (300, 600 and 900 °C. As per Gerges et.al. (2015), cold joint reduces the splitting tensile strength of by nearly 55%. It was concluded that concrete cylinders with diagonal joint showed 30% loss of resistance when subjected to compressive load and concrete cylinders with diagonal joint showed 42% loss of resistance when subjected to indirect tensile strength whereas cylinders with horizontal joint did not show major loss in strength when subjected to compressive load(Torres et al., 2016). As for durability of concrete, it was noted that the effects of drying–wetting and freezing thawing had significant loss due to cold joints (Bekem Kara, 2021)fresh concrete was poured into molds filling them half in order to create a horizontal cold joint and after 0, 60, 120 and 180 min additional concrete was poured to top off the molds. The specimens were subjected to compressive, flexural, splitting tensile and concrete steel rebar pullout testing. In the second part of the study, two types of concrete were prepared to carry out durability experiments. Concrete specimens with and without cold joints were subjected to drying wetting, freezing thawing and high temperatures (300, 600 and 900 °C. The flexural strength of the concrete in presence of the cold joint decreases which decreases the moment capacity of the concrete as per Nagib N. Gerges et. al. Similar to that, from the results it was found that the finite element created for cold joint in flexural test has a reduction of flexural strength with the increase due to the presence of cold joint in horizontal, vertical and slanted orientation of the cold joint (Lamichane, 2019).

Ordinary Portland Cement (OPC) with normal consistency of 29.5 % with initial setting time of 118 minutes and final setting time of 280 minutes was used throughout the experiment. Aggregates obtained from nearby RMC was washed thoroughly and sundried before use. The coarse aggregates for the experiment included aggregate size of maximum 20mm with fineness modulus of 7.22 and specific gravity of 2.66 was used. Fine sand of grading zone I with fineness modulus of 3.16 and specific gravity 2.61 was used. The ratio for mixing for plain concrete grade M25 was 1:1.609:2.566 as per IS-10262:2009 with water cement ratio of 0.45.Cement slurry in the ratio of 1:1 and chemical admixture was used for joint treatment after chipping. In-situ compressive strength assessment of concrete in under-construction residential buildings and Practice of Concrete Production at Gaindakot municipality by Aryal and Mishra,2020, Cement Consumption Pattern of Pokhara, Economic Operation of Cement by Mishra et al(2020), Cement Handling Behaviour at Bhatbhateni by Mishra and Chaudhary (2018), Operational Relation of Cement to Estimate Strength by Mishra et al, (2020) and Quality Assessment by Mishra and Jha (2019) shows the practice of concreting is not accurate in this situation is cold joints resulted into loss of strength then society might have been losing structural and economic loss.

Study Area

The study is to be fully laboratory based and proposed to be carried in laboratory of Infrastructure Development

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Directorate, Pokhara. Tensile tests which are not available at the lab can be conducted at Paschimanchal Campus Laboratory. Raw materials for concrete like sand, aggregates can obtained from different crushers within the valley. Since Fewa RMC is nearest to the proposed laboratory, the raw materials can be collected from the crusher. The main quarry site for these crushers is located at Kotre, Hemja and Dobilla. Readily available OPC can be used for conducting the test. The concrete shall be M25 grade for the tests as most of the high-rise buildings and apartments are usually made on M25 grade of concrete.

Objective of Study

The study of cold joint on strength of concrete can be actually beneficial in daily construction practices of concreting specially during mass concreting. This study will help many clients, contractors and other construction workers to focus on the construction practices during mass concreting. The objectives of the study includes:

- To observe the consequence of cold joints on strength of concrete.
- To study the effect of admixtures or rich cement mortar on the effect of cold joints.

Methodology

Compressive strength and split tensile strength were tested for the strength of concrete due to cold joint. Aggregates were thoroughly washed and sundried before use. Mixing was done with the help of mechanical mixer for 3-4 minutes.

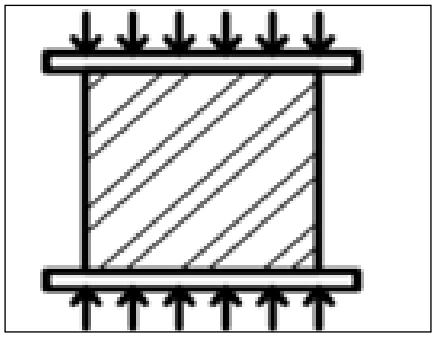

Figure 1.Cube without Joint

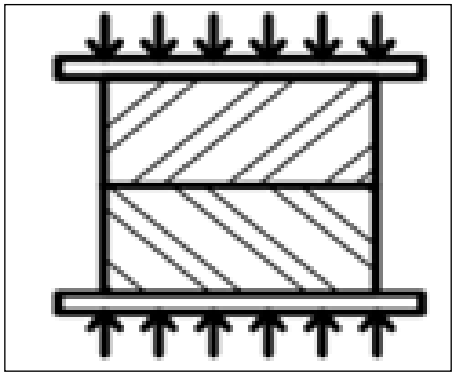

Figure 2.Cube with Horizontal Joint

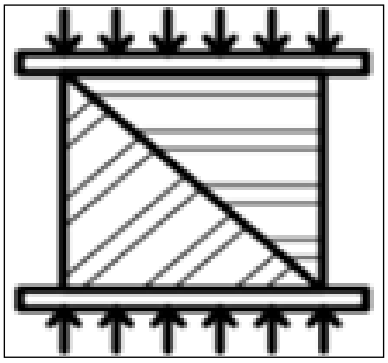

Figure 3.Cube with inclined Joint

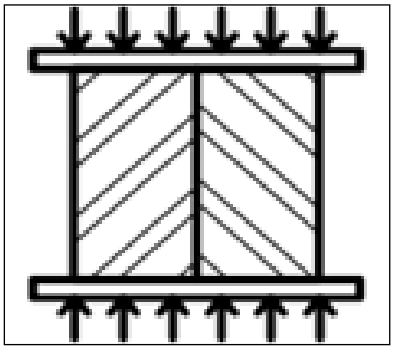

Figure 4.Cube with Vertical Joint

Cubical samples were tested for compressive strength and cylindrical samples for split tensile strength. Cubical samples included cubes without joint , cube with horizontal joint, cube with inclined joint and cube with vertical joint whereas cylinder without joints and cylinder with horizontal joint.

Minimum of three samples were taken for each test. Half sample molds were filled with the concrete mix and remaining half of sample was filled after 24 hours to create a cold joint using plywood. Cement slurry in the ratio of 1:1 and chemical admixture in the ratio of 1 ltr/kg/m^2 was applied on the jointed surface after chipping for joint treatment. Casted samples were cured in the curing pond for 7 days and 28 days before testing. During compressive strength test for cubes with horizontal joints, the line of

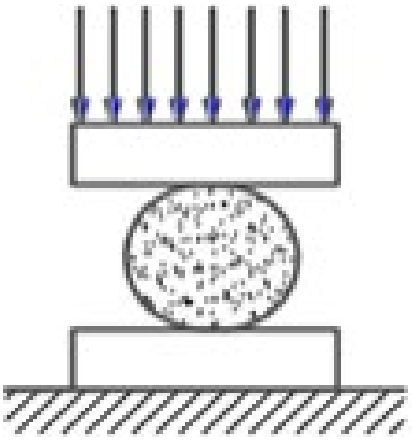

Figure 5.Cylinder without Joint

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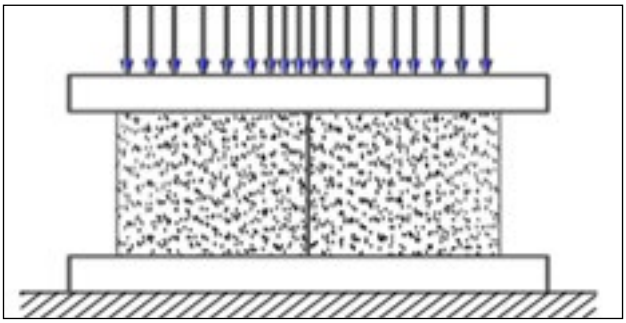

Figure 6.Cylinder with Horizontal Joint

action of compressive force was perpendicular to the joint while for cube with vertical joint , the line of action of compressive force was kept parallel to the joint. The split tensile strength of cylinder with horizontal joint was done by placing the joint at the center of the loading plate.

Results

Cube with Joints

The table shows the compressive strength of cubical samples with and without joints. It is clear that the strength of the cube decreases with the presence of joints. The target strength is lost but the characteristic strength is however met even due to presence of joints. The effect of joint is found similar in all types of joints in the experiment.

The above table shows that the use of cement slurry (1:1) is not much effective in recovering the effect of horizontal joints in compression. However, the effect is reduced by 21.51% in case of cube with vertical joints.

The above table shows that the use of chemical admixture as well is not much effective in recovering the effect of horizontal joints in compression. However, the effect is reduced by 30.81% in case of cube with vertical joints. The use of chemical admixture is effective than cement slurry (1:1) in case of cube with vertical joints.

Table 1.Compressive Strength of Cube on 28 days

S. No.	Description	Average Compressive strength without surface Treatment	Average Compressive Strength (Mpa) with Surface Treatment	Recovery in Strength with respect to previous joint strength %	Loss in Strength with respect to target strength%
1	Cube with Horizotal Joint	25.93	25.33	-2.31	-20.92
2	Cube with Vertical Joint	25.48	33.33	30.81	4.06

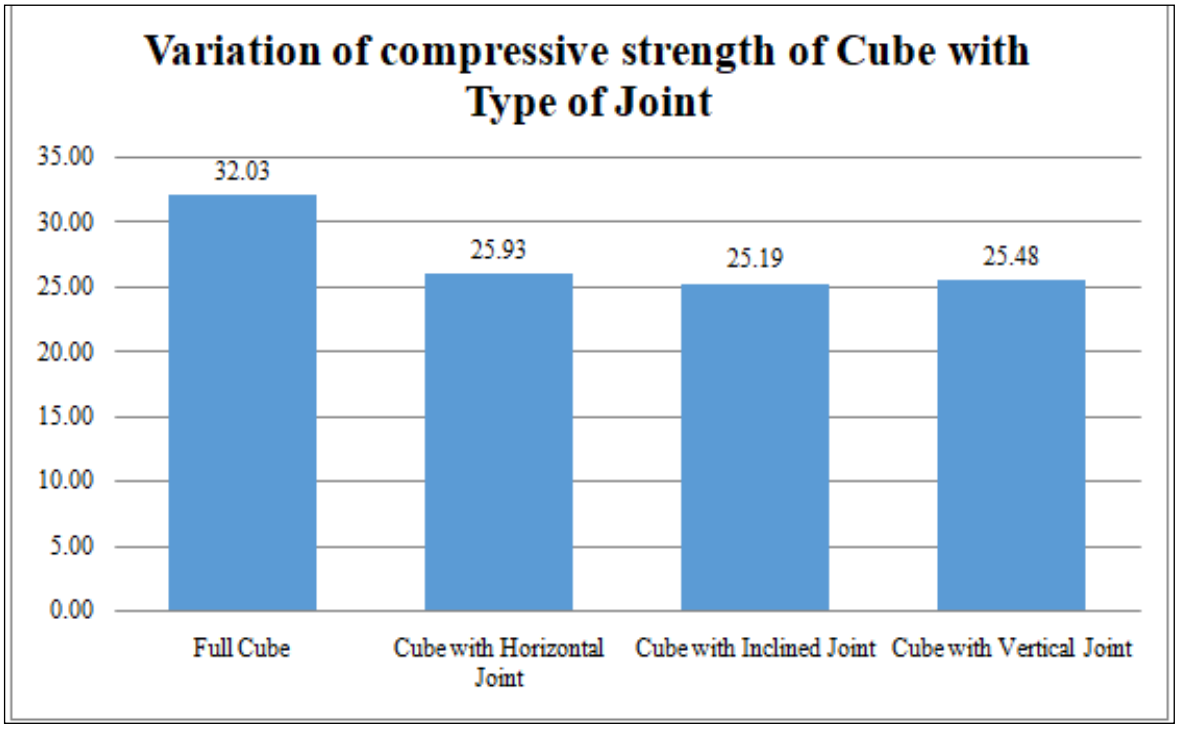

Figure 7.Variation of Compressive strength of Cube with type of joint on 28 days

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Table 2.Jointed Cubes with Surface Treatment with Cement Slurry (1:1)

S.No.	Description	Average Split Tensile Strength (Mpa)	Loss in Strength %	Recovery in Strength %
1	Cylinder without Joint	2.83		
2	Cylinder with Joint	2.17	-23.32	
3	Cylinder with Joint after application of cement slurry	2.47	-12.72	13.82
4	Cylinder with Joint after application of chemical admixture	2.55	-9.89	17.51

Table 3.Jointed Cubes with Surface Treatment with Chemical Admixture

S.No.	Description	Average Compressive Strength (Mpa)	Loss in Strength %
1	Cube without Joint	32.03	
2	Cube with Horizotal Joint	25.93	-19.04
3	Cube with Inclined Joint	25.19	-21.35
4	Cube with Vertical Joint	25.48	-20.45

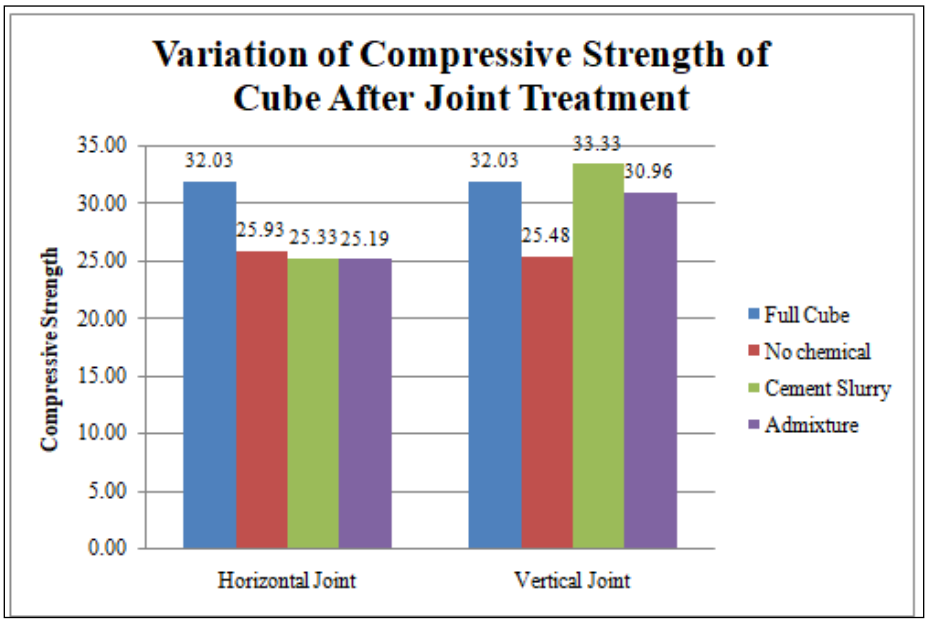

Figure 8.Variation of Compressive Strength of Cube after Joint Treatment at 28 days

Table 4.Split Tensile Test of Cylinder

S. No.	Description	Average Compressive strength without surface Treatment	Average Compressive Strength (Mpa) with Surface Treatment	Recovery in Strength with respect to previous joint strength %	Loss in Strength with respect to target strength %
1	Cube with Horizotal Joint	25.93	25.19	-2.85	-21.35
2	Cube with Vertical Joint	25.48	30.96	21.51	-3.34

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The figure shows the effect of joint in cube with vertical and horizontal joints and the strength achieved after the surface treatment using cement slurry (1:1) and chemical admixture. It is clear that the surface treatment is effective in reducing the effect in vertical joints rather than horizontal joints.

Split Tensile Strength

Split Tensile Strength of Cylinder at 28 days

The above table shows the strength of cylinder at with and without joints. It is also clear that the effect of joint is seen

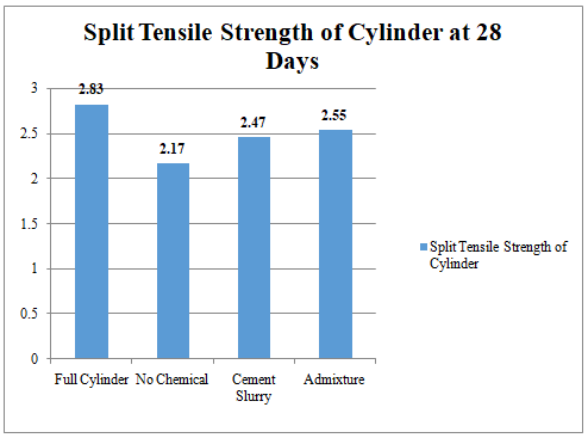

Figure 6.Cylinder with Horizontal Joint

in cylindrical specimen during split tensile strength. The split tensile strength of cylinder has decreased upto 23.32% due to presense of horizontal joint in the mid section. However, the use of surface treatment due to cement slurry (1:1) and chemical admixture has recovered the loss strength by 13.82% and 17.51% respectively. The use of chemical admixture seems effect for cylindrical specimen.

Conclusion

1. From all the above figures it is obvious that cold joint causes decline in strength of concrete in compression and tension.
2. The compressive strength has been observed to decrease by 22-25% while tensile strength has been observed to decrease by 23%. The effect of cold joint is seen more in concrete in tension than in compression.
3. The effect of cold joint is also more in concrete with vertical joint than in concrete with horizontal joint when subjected to compression. The decrease in strength in compression and tension has been observed due to lack of interlocking between concrete mix between the first and second batch due to formation of cold joints. Also when the load path is along the direction of cold joint, which is a plane of weakness, concrete seem to perform poorly.
4. In case of split tensile test of concrete, presence of joint decreases the tensile strength by 23%.
5. The use of chemical admixture and cement slurry as joint surface treatment shows improvement in concrete with vertical joints and during split tensile strength of cylinder but such treatment doesn't seem to be much effective in concrete with horizontal joints when subjected to compression. The use of cement slurry (1:1) has increased the compressive strength of concrete with vertical joint by 30.80% and split tensile strength of cylinder by 13.82%.
6. The use of chemical admixture has increased the compressive strength of concrete with vertical joint by 21.50% and split tensile strength of cylinder by 17.51%.

Recommendation

The formation of cold joints in large infrastructure projects with huge amount of concreting in unavoidable. So, it is recommended to treat the cold joints properly with rich cement slurry or chemical admixture whichever possible for effective concreting and strength of the structure. However, the use of cement slurry after surface chipping is more cost effective in joint treatment than chemical admixture as cement slurry can be made easily and is readily available.

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