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A Study on Consumption of Temperature Control Requirements for the Construction of Mass Concrete of Members

[1] Rohit Kumar, [2] Mr. Abhishek Rana [3]. Mayank Chauhan
[1]M. Tech Student, ,[2 Assistant] Professor 3. Assistant Professor
Structural Engineering,
Shri Venkateshwara University Uttar Pradesh, India.

Abstract — Special precautions must be taken when constructing concrete elements designated as mass concrete. These precautions may be satisfied through the formation of a mass concrete specification. Temperature requirements must be established to mitigate thermal cracking and delayed ettringite formation (DEF), both of which cause premature deterioration of concrete. The temperature difference between the concrete core and outside edge must be limited to prevent excessively wide thermal cracks. To prevent DEF, the maximum concrete temperature must be limited to 160°F or 185°F, depending on the amount and type of supplementary cementing materials (SCMs) used. When designating a member as mass concrete, a minimum element dimension must be established to ensure that the temperature limits are not exceeded. These temperature and size limits are investigated here to develop an elan specification for mass concrete construction.

Temperature data from seven elan housing projects elements were collected using temperature sensors. Maximum temperatures and temperature differences were used to determine appropriate temperature limits for the elan housing projects specification as well as validate the temperature predictions of the Concrete Works software used for the same elements. Once Concrete Works' accuracy was determined, 480 theoretical concrete placements were statistically analyzed to determine that the use of low coefficient of thermal expansion (CTE) concrete and SCMs play a major role in limiting maximum temperatures and temperature differences. A mass concrete specification was then developed, which designates mass concrete at least dimensions, maximum temperature limits, and maximum temperature difference limits based on SCM use and concrete CTE.

Keywords: Concrete, Coarse Aggregate, Compressive Strength, Temperature control concrete

I.INTRODUCTION

According to ACI 116R; mass concrete can be defined as "any volume of concrete with dimensions larger to require that measures be taken to cope with generation of heat from hydration of cement and attendant volume change to minimize cracking". Generally, structural members with the least dimension greater than 1.22 m fall into this category. We have limit i.e 1.5 mtr. The early-age temperature generation in mass concrete structures leads to serious impact on its durability. The temperature differential of high magnitude in such structures can result in large temperature-induced stresses which can cause cracking particularly at an early age. The high temperature differential is mainly caused by a large amount of heat generated, due to hydration of cementitious product, in the core of structure that is dissipated at a very slow pace or is not dissipated at localized region, representing a true adiabatic condition. The temperature regime in mass concrete structures is affected by many factors, such as ambient temperature, wind speed, water temperature, intensity of solar radiation and shading effect, temperature of foundation, and especially amount of hydration heat which is caused by the cement type and its quantity. In addition, the temperature distribution in the mass concrete is also influenced by other factors, such as schedule of placement, size of aggregate used in mass concrete, initial temperature of concrete mix, curing condition, etc. As a result, high temperature gradient occurring during the construction may cause significant tensile stresses and lead to thermal cracks. The temperature difference between the inner zone and the outer surface of the mass concrete is the reason causing the formation of thermal stress. If the tensile stress is larger than the tensile strength of the mass concrete, thermal cracks form on the surface of the concrete structure, especially at an early age. To avoid the formation of thermal cracks, a general condition is that the temperature gradient ΔT should not exceed 20°C and peak temperature should not exceed 70°C in within 72 hours. On another aspect, to minimize the temperature difference between the inner zone and the outer surface of mass concrete causing

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thermal cracks, past research indicated several curing methods by using different types of insulation material together with its thickness, such as polystyrene and sand layers. In addition, cooling pipe system is quite a perfect solution to reduce hydration heat in the core of mass concrete. In the present study, temperature gradients between inner and outer zones of mass concrete are investigated and the temperature profile with time and its maximum value is presented. In recent years several studies have been done to study and control the adverse effects of excessive temperature gradients in mass concrete work. These studies involve various experimental as well as simulation-based approaches. By utilizing Distributed Temperature Sensing (DTS) technology, J. Ouyang et al. proposes a framework for cracking control for a mass concrete structure in a reservoir project. The study demonstrated that the DTS system with fiber optic cable may be used to provide a novel platform for cracking control for a gigantic concrete building under construction. This cracking control is primarily reliant on thermal stress modelling, which is in turn reliant on the values and parameters of the concrete's thermal and mechanical characteristics. The temperature field and temperature time histories for the core concrete of the enormous pier induced by hydration heat were studied by

Y. Huang et al. using a 1:5 scaled segmental model test of an arch bridge. Study suggests that the temperature of the concrete climbs rapidly but falls slowly. The temperature gradients between the center and the surfaces of sections were found to be between 25°C to 30°C. Through a three-dimensional finite-element simulation of the hydration heat in concrete with a forced cooling system, the study also showed experimentally that forced cooling helps reduce the interior temperature but, it leads to a reverse thermal gradient around the cooling pipe

II. MATERIAL USED

Cement

The cement taken was Ordinary Portland Cement (OPC) of 43 grade of consistent consistency, compliant to IS 8112-1989 [15- 19]. The test for specific gravity, normal consistency, initial and final setting time and 28 days compressive strength have been conducting Table 1.

Fly Ash

In the examination Class C fly ash was used. Class C fly ash generally comes from coal which may generate an ash with higher lime content, generally more than 15%, often as high as 35%. Fly ash obedient to IS 3812 (part-1) has been used and identical merger of fly ash with cement was ensured.

Table 1: *Physical Properties of Ordinary Portland Cement.*

Sr. No.	Characteristics	Values Obtained	Standard Values
1.	Specific Gravity	3.17	-
2.	Normal Consistency	29%	-
3.	Initial Setting Time	1 hour 35 min	Not to be less than 30 minutes
4.	Final Setting Time	3-hour 52 min	Not to be greater than 600 minutes

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Table 2: *Physical Properties of Fine Aggregate.*

Characteristics	Type	Specific Gravity	Fineness Modulus	Grading Zone	Water absorption
Value	Natural Sand	2.72	2.55	II	1.04%

Table 3: *Physical Properties of Coarse Aggregate.*

Characteristics	Colour	Shape	Maximum Size	Specific Gravity	Fineness Modulus	Water absorption
Value	Grey	Angular	10 mm	2.63	6.61	.92%

Fine Aggregate

The fine aggregate (river sand- Badarpur) used in the experimental work is nearby procured. Sieve analysis of the fine aggregate was accepted out in the laboratory as perIS383-1970, and the results are tabulated in Table 2.

Coarse Aggregate

The aggregates which are retained over IS sieve 4.75 mm are called as coarse aggregate. The coarse aggregate used in the present study was nearby available crushed stones of maximum size of 10 mm. exact gravity and other physical property of coarse aggregates are given in Table 3.

Fig- 1 Coarse Aggregate

Fly Ash

The physical properties and chemical composition of pond ash is given in Table4.

Fig. 2 fly Ash

Table 4: *Physical Properties of fly Ash.*

Characteristics	Specific gravity	Dry unit weight	Plasticity	Absorption
Value	2.1-2.7	7.07-15.72 kN/m^3	None	0.8-2.0%

Super Plasticizer

Workability of concrete decreased with the add to pond ash content, which is included by using super plasticizer. In this study For soc SP430 super plasticizer is used.

III. EXPERIMENTAL WORK

Concrete Mix Design

The mix design of conservative concrete having the design procedure as per given in IS 10262:2000 adopted for the M-40 grade of concrete. The ratio of the ingredient's material is 1:2.07:2.65 and the water/cement ratio is 0.40 the for all the mix proportions. The concrete specimens are prepared with pond ash for the M40 grade of concrete. Three cubes of each variation of pond ash are casted and the average of three test results is taken for the accuracy of the results.

Table 5: *Mix proportion of M-50 TCC*

Cement	360 kg/m^3
Water	159 kg/m^3
Fine Aggregate	475 kg/m^3
Coarse Aggregate	961 kg/m^3
Admixture	4.40 liters
w/c	0.29

Mix Proportions

Fly ash is added in the normal concrete and prepared nine batches of mixed proportions in the laboratory. Six cubes for each mix proportions and three cubes tested after 7 days and 28 days and 56 days of curing. Take the results as the average value of the three cubes. In mixed addition, only fly ash with replacement of fine aggregate. as shown in Table 6.

Table 6: Proportions of Various Concrete Mixes.

MIX NO.	F1	F2	F3
	0%	0%	0%
Fly ash	10%	15%	35 %
NO. OF CUBES	9	9	9

Compressive strength test

Concrete samples were made by using ordinary Portland cement. The work of art of the mortar mix is shown in table -2. Moulds with dimensions of 150 mm× 150 mm× 150 mm. After casting, all molds were located in a normal warmth of room with a relation dampness of more than 90% for a phase of 24h. After de-moulding, the specimens were placed for the curing At the time of testing, cubes were took out from the water, excess water was wiped out by jute cloth and placed it on the platform of compression testing machine. 7th and 28thdays and 56 days compressive strength was measured. The compressive strength result shown in table no.7

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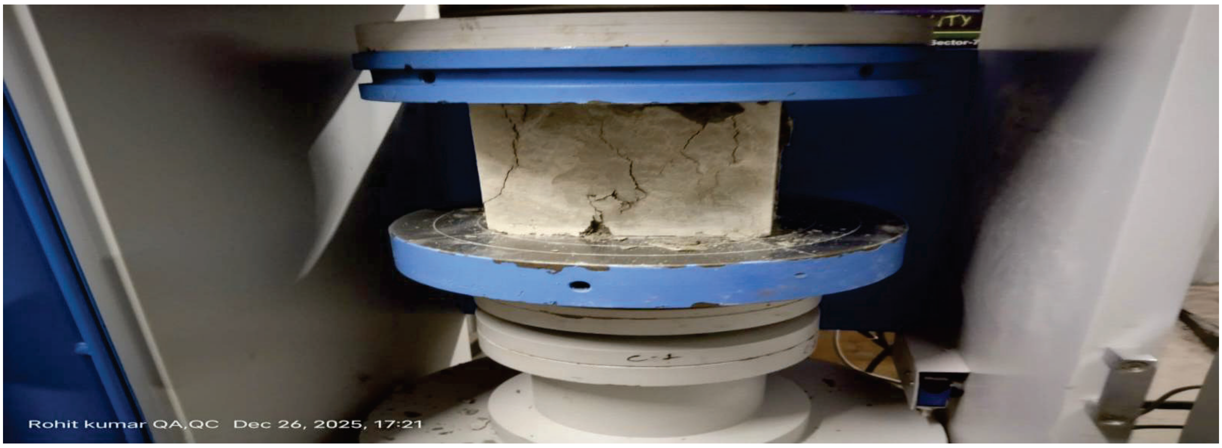

Fig. 3 Compressive strength test

IV. RESULT AND DISCUSSION

Compressive Strength

The replacement of sand by pond ash using flysh was done in proportion of 10%,15%, 20% and also cement was replaced with flyash in proportion of 0% , 15% and 35%. Its effect on properties of concrete was investigated. The variation in compressive strength and ultrasonic pulse speed on varying percentage of fly ash using is discussed in Table7.

Variation of Compressive Strength forM-50 TCC Concrete Using fly Ash Only

Compressive strength of concrete has been obtained at different percentages of pond ash in mix F1(10%), F2(15%), F3(20%), as shown in Figures 1 and 2.

Table 7: Results of Compressive Strength after 7days and 28 days. and 56days

Sr. No.	GRADE	DOC	DOT	AGE DAYS	WEIGHT, KGS	LOAD, kN	C STRENGTH, MPA	AVG STRENGTH, MPA
1	M50	09-03-2026	09-03-2026	7	8.310	1189.20	52.85	
2	M50	09-03-2026	09-03-2026	7	8.280	1115.8	49.59	51.60
3	M50	09-03-2026	09-03-2026	7	8.340	1178.20	52.36	
4	M50	30-03-2026	30-03-2026	28	8.300	1698.0	75.46	
5	M50	30-03-2026	30-03-2026	28	8.230	1458.4	64.81	69.49
6	M50	30-03-2026	30-03-2026	28	8.220	1535.1	68.22	
7	M50	27-04-2026	27-04-2026	56	8.170	1795.10	79.78	
8	M50	27-04-2026	27-04-2026	56	8.210	1785.70	79.36	79.89
9	M50	27-04-2026	27-04-2026	56	8.260	1812.20	80.54	

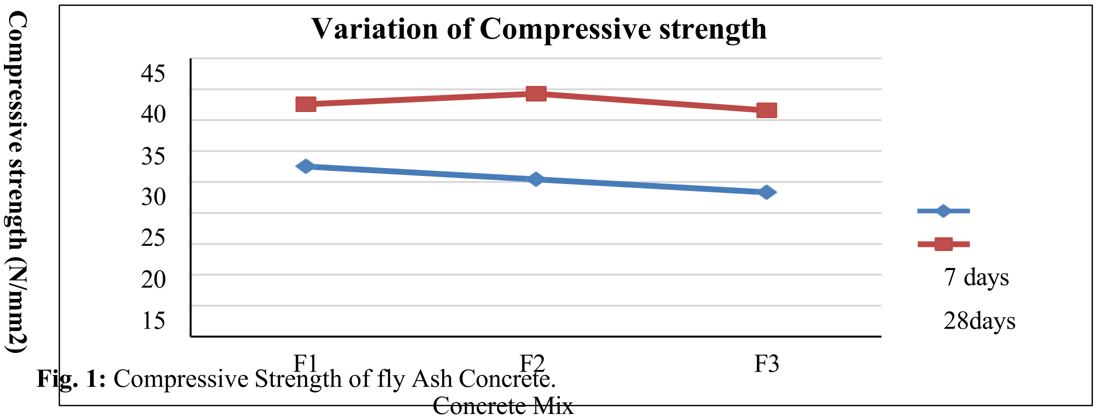

Fig. 1: Compressive Strength of fly Ash Concrete.

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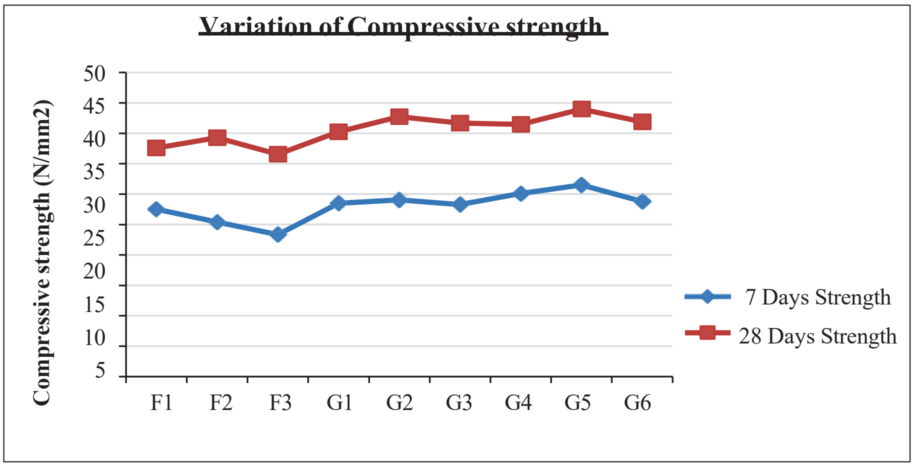

Fig. 2: Compressive Strength of fly Ash Concrete of All Mixes.

V. CONCLUSION

On the basis of the results obtained from present study, following conclusions are.

- The physical properties of the constituent of the pond ash replaced concrete satisfy the needs as per respective codes.
- The density of concrete reduces with the increase in the percentage of pond ash and the compressive strength of concrete with pond ash increases with increased curing period.
- Workability of concrete decreases with the increase in pond ash and hence the super- plasticizer for soc SP430 is used in this study.
- The compressive strength of 15% cement and 5% flyash replaced concrete is found to be highest after 7 and 28 days of curing but the compressive strength for 28 days is found to be slightly higher for 5% flysh replacement only than the combine replacement of pond ash and flysh.
- Thus, the compressive strength increases up to 15% pond ash and 5% flyash by weight in place of sand and cement respectively and with an addition of pond ash more than 35% , the compressive strength decreases. it shows the optimum percentage for replacement of fine aggregate with pond ash in concrete is15% pond ash using 5%alccofine.
- Considering the compressive strength criteria and cost of concrete, the replacement of fine aggregate with pond ash is feasible and the variation of strength of ponded ash concrete in comparison to reference concrete lies within ± 10% up to the age of 28 days and 56days for various mixes.

- **Key Notes (Important for QA/QC & Monitoring**

Sensors should be installed at **minimum 3 locations (plan-wise)**:

- Centre
- Edge
- Corner

This helps capture **temperature variation across the raft**

Data should be recorded at **regular intervals (e.g., every 1–2 hours initially)**

Critical for controlling:

- **Thermal cracking**
- **Maximum core temperature**

Temperature differential (core vs surface

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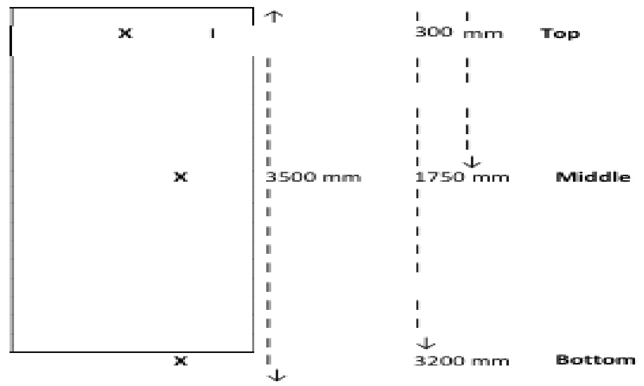
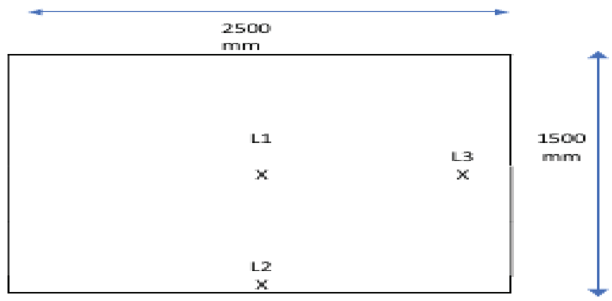
Locations of the Temperature Sensors



Temperature sensors at different depth of the foundation (Typical elevation of the foundation)



Different Locations in the mockup and pour where temperature sensors will be installed
(Typical Plan of the Mockup)

REFERENCES**Temperature Rise Study in Concrete Mock-up**

Instrumentation & Sensor Placement

- A nominal **16 mm diameter steel reinforcement bar** shall be used for fixing and placing temperature sensors at designated locations (to be finalized by the sponsor).
- At each location, **three temperature sensors** shall be installed at:
    - Bottom
    - Middle
    - Top of the concrete foundation
- At **Location 1**, temperature sensors shall be placed at:
    - **300 mm above bottom**
    - **Middle depth**
    - **300 mm below top surface** (final positions to be mutually agreed)

Additionally, **one sensor shall be installed outside the concrete foundation** to record ambient temperature

Site Requirements

- Continuous **220V power supply (24×7)** for operation of the data logger.
- Proper **safety and security arrangements** for the data logger at site.
- Adequate protection of **data logger and PT-100 sensor cables** before and after concreting.
- Availability of manpower during installation:
    - 1 Site official
    - 2 Skilled labours
    - 1 Carpenter
    - 1 Electrician

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Precautions

- Ensure that **sensor cables are not damaged** during concrete placement and vibration.
- Proper routing and securing of cables must be done prior to casting.

Testing Duration

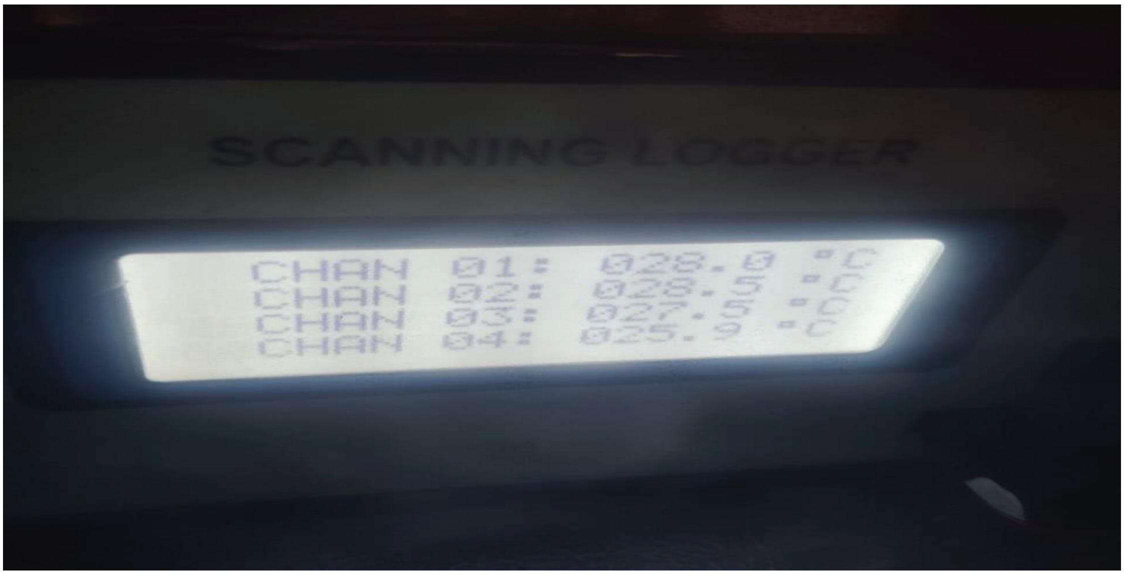
- A **minimum period of 7 days** from the date of concreting is required to complete temperature monitoring and data collection.

Details of Equipment and Thermocouple

1. Equipment Required

The following equipment will be used to monitor temperature development in concrete:

- **Data Logger**
  - Multi-channel automatic temperature recording system
  - Capable of continuous monitoring (24×7)
  - Stores temperature data at predefined intervals (e.g., every 10–30 minutes)
- **Thermocouples (Temperature Sensors)**
  - Type: Generally, **Type K (Chromel–Alumel)** or equivalent
  - Suitable for range: 0°C to 100°C or higher
  - Accuracy: ±0.5°C (typical)
- **Connecting Cables**
  - Shielded and insulated wires to connect thermocouples to data logger
- Resistant to moisture and site conditions
- **Protective Conduits / PVC Pipes**
  - Used to protect thermocouple wires inside concrete
  - Prevent damage during concreting



Data Logger Specifications (Temperature Monitoring System

- Data is stored directly on a USB pen drive in an **MS Excel–compatible file format**, enabling easy access and analysis.
- The system is **microprocessor-based** and supports linearized inputs for:
  - **J, K, R type thermocouples**
  - **PT100 temperature sensors**
- Equipped with a **4-line alphanumeric LCD display with backlight** for clear and user-friendly operation.
- Provides **automatic cold junction compensation** for thermocouples and supports **3-wire input configuration for PT100 sensors**, ensuring accurate temperature measurement.
- Supports **1 to 16 selectable input channels**, allowing flexible configuration based on requirement.
- Offers both **Auto and Manual scanning modes** for channel monitoring.
- **Logging interval (rate of data recording)** is user-configurable in **minutes and seconds**.
- Includes **digital offset adjustment** for individual channels to correct measurement deviations.

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- Built-in **Real-Time Clock (RTC) with battery backup** ensures continuous recording of data along with accurate **date and time stamping**, even during power failure.

10	Real Time Clock	Adjustable Calendar (Month/Date) and Time (Hrs: Mins)
11	Accuracy	±1˚C ± 1 Least Significant Digit for Thermocouples ±0.1˚C ± 1 Least Significant Digit for PT100
12	Power Supply	230V AC ± 15% at 50/60Hz
13	Mounting Type	Panel Type
14	Front Facia	96mm x 192mm

- No additional or complex software is required for data handling—data saved on the pen drive can be directly opened in Excel, providing:
    - Simple data management
    - Large storage capacity

PT-100 Temperature Sensor Specifications

- Metallic body suitable for rugged conditions
- Designed for direct embedment in concrete
- High reliability with accurate data acquisition
- Compatible with all standard data loggers (linear output)
- Temperature range: **-20°C to 150°C**
- with variable cable lengths as per requirement
- Accuracy: ±**0.2°C**
- Resolution: **0.1°C**

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